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DEPARTMENT BULLETIN No. 1264

Washington, D. C. ▼ February 21, 1925

FOREST PLANTING IN THE INTERMOUNTAIN REGION

By

C. F. KORSTIAN, Associate Silviculturist,
Appalachian Forest Experiment Station, and F. S. BAKER, Forest Examiner, Forest Service

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INTRODUCTION.

The "intermountain region" is a term used to include the great expanse of country lying between the Sierra Nevada Mountains and the Rocky Mountains proper, bounded on the north by the Salmon River and on the south by the Colorado River, and situated mainly in the Great Basin and the Snake River watershed. This territory is prevailingly arid, but upon the higher mountain ranges occur extensive timbered areas the bulk of which are now included within the boundaries of national forests. There are also within these boundaries many large tracts of potential forest land now bearing no commercial tree growth, whose highest value can never be attained until they are made to produce timber. This has been recognized by the Forest Service, and plantations and seedings have been made to test methods and costs. Direct seeding was unsuccessful and was soon abandoned as a method, but plantations of trees started in nurseries proved conclusively that this method can be used to reforest denuded lands in this region. Planting work has been discontinued here, however, in view of the opportunity to secure better results, both in survival and growth, in other regions where the reforestation of national forest lands is of equal or greater importance.

The results have shown many of the possibilities as well as the difficulties of planting in the mountains of an arid region and indi-

cate the procedure that should be followed to secure the best results. The forestation problems peculiar to this region exist rather in field planting than in the propagation of nursery stock. The artificial conditions found in the nursery bed are essentially uniform the country over, and the accepted methods are fairly well standardized and are generally applicable (*7, 8, 9*).[1] Under the natural conditions of field planting, the intermountain region presents more special problems due to peculiarities of this particular region. For this reason, this bulletin will treat field planting more extensively than the preceding operations of seed collection and nursery practice. However, certain deviations from usual practice and certain unusual difficulties experienced in this particular region, even in the artificial growing of the nursery stock, must be considered.

SEED COLLECTION.

Forest planting must necessarily begin with the collection of the seed. In this region seed collecting has been confined almost entirely to squirrel caches, because logging operations have never been large enough to make the usual method of collecting seed from felled trees economical. Collecting from squirrel caches is cheaper than any other method tried (Pl. I) and can be done after the cones on the trees have shed the seed; and seed obtained in this manner usually has a high germination percentage. Seed of western yellow pine (*Pinus ponderosa* and *P. ponderosa scopulorum*), Douglas fir (*Pseudotsuga taxifolia*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmanni*), and blue spruce (*Picea parryana*) has been collected by this method at various times and in quantities ranging from a few pounds up to as high as 6,000 pounds in a single operation.

The exact time of the ripening of the cones depends somewhat on the species, the season, and the locality. By September 15 to 20 the squirrel caches are usually fairly well filled, and the gathering of cones should begin about that time. If delayed to a much later date, snow and cold weather may make the work disagreeable and expensive.

It is not difficult to locate the caches, which are usually found in some moist place under rotten logs or stumps, or under brush, and usually close to groups of good seed trees. An average of 4 to 5 bushels of cones may be collected from one cache in good seed years, while as high as 15 bushels have been taken. The cones should be collected in sacks, including as little litter as possible, and at the close of each day's work the sacks should be taken to some central point where the drying can be started without delay.

Since the collection of the cones can not usually be started until September 15 or later, the time for outdoor drying is short before inclement weather sets in throughout the intermountain region. It is therefore necessary to start the drying as soon as the first lot of cones is obtained. No special means of extraction is necessary with any of the species used in this region. Solar drying is the rule (Pl. II, fig. 1), although artificial heat is sometimes necessary with lodgepole pine.

[1] Italic numerals in parentheses refer to "Literature Cited" page 56.

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COLLECTING SPRUCE CONES FROM A SQUIRREL CACHE. BIG COTTONWOOD CANYON, WASATCH NATIONAL FOREST, UTAH

F-12953A

FIG. 1.—DRYING WESTERN YELLOW PINE CONES IN THE SUN ON CANVAS SHEETS. LA SAL NATIONAL FOREST, UTAH

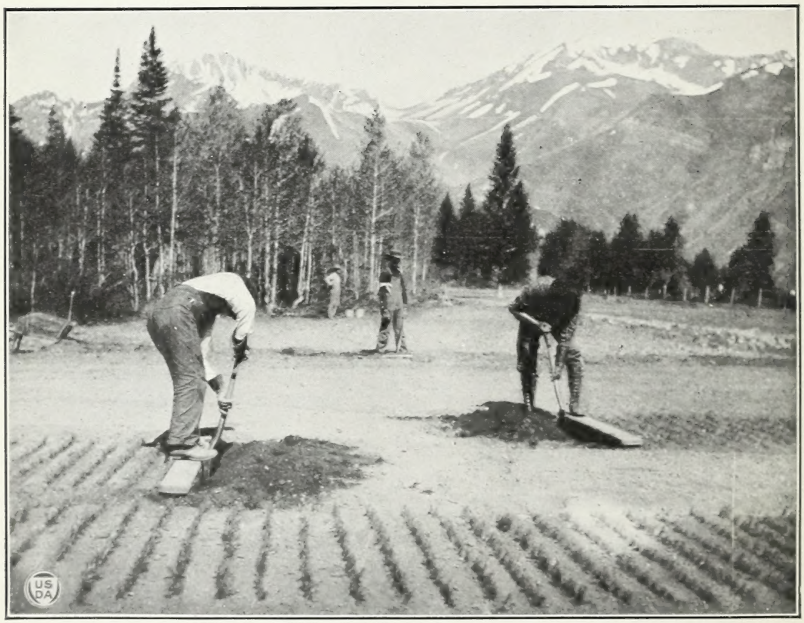

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FIG. 2.—OPENING OF TRENCH IN TRANSPLANTING DOUGLAS FIR SEEDLINGS. IN THE FOREGROUND THE SLOPE OF THE TREES RESULTING FROM TRANSPLANTING MAY BE SEEN. COTTONWOOD NURSERY, UTAH

When thoroughly dry, the seeds are removed from the cones by various methods, such as raking the cones, flailing them, or putting them through a cone shaker.

YIELD FROM CONES.

Taking into consideration the principal collecting operations in the intermountain region, the minimum, maximum, and average yields of seed per bushel of cones for the various species are given in Table 1.

TABLE 1.—*Minimum, maximum, and average yields of seed per bushel of cones, Utah and Idaho.*

Species.	Minimum yield.	Maximum yield.	Average yield.
	Pounds.	*Pounds.*	*Pounds*
Western yellow pine	0.75	2.00	1.32
Douglas fir	.36	1.33	.76
Engelmann spruce	.40	1.00	.50
Blue spruce	.75	1.25	1.00
Lodgepole pine	.34	1.00	.54

The smallest, largest, and average number of seeds per pound, which were obtained from a large number of samples collected in 1911, 1914, and 1915, are given by species in Table 2.

TABLE 2.—*The smallest, largest, and average number of seeds per pound obtained from samples collected in Utah and Idaho in 1911, 1914, and 1915.*

Species.	Smallest number of seeds.	Largest number of seeds.	Average number of seeds.
Western yellow pine (Idaho)	8,280	12,240	9,707
Western yellow pine (Utah)	13,000	19,063	15,955
Douglas fir	23,720	48,695	34,002
Lodgepole pine	76,632	115,132	81,560
Engelmann spruce	69,000	135,082	80,500
Blue spruce	80,000	85,000	83,750

COST OF SEED.

The cost of collecting seed depends on so many factors, such as the abundance of cones, locality, cost of labor, and size of operation, that it is difficult to give a reliable cost figure. The minimum, maximum, and average cost figures for some of the principal operations in this region are given in Table 3.

TABLE 3.—*Minimum, maximum, and average cost of clean seed per pound, Utah and Idaho.*

Species.	Minimum cost.	Maximum cost.	Average cost.
Western yellow pine	$0.41	$2.33	$0.87
Douglas fir	.69	6.20	.91
Engelmann spruce	1.65	5.52	2.19
Blue spruce	.78	2.16	1.47
Lodgepole pine	1.88	7.36	2.40

The high cost per pound of lodgepole pine seed is due to the low yield and the difficulty in extracting the seed, artificial heat frequently being necessary to open the cones.

NURSERY PRACTICE.

The beginning of successful forest planting lies in the nursery practice. Because the production of nursery stock is not an end in itself but merely a means to an end, the fundamental principles of ordinary nursery practice were sometimes overlooked in the earlier attempts at forest planting in this region. Cheapness of production rather than the quality of stock was frequently the objective. Likewise, the size and vigor of the top rather than root development was too often the criterion by which the quality of the planting stock was judged. In the arid intermountain region, where the young tree is taxed to the utmost to establish itself after planting under relatively adverse climatic conditions, such standards can only result most disastrously.

In addition to the small ranger nurseries which were in operation during the earlier planting work in the intermountain region, three large nurseries were established and were in operation for a number of years—the Cottonwood and the Beaver Creek Nurseries on the Wasatch National Forest, and the Pocatello Nursery on the Cache National Forest. The Cottonwood Nursery had been in operation 14 years when it was decided to curtail planting work in the region, temporarily at least, on account of the relatively high cost of planting and the relatively adverse climatic conditions. The deficiencies of these nurseries for the growing of forest trees are not unusual, but are worthy of brief notice to aid in the selection of better sites in the future whenever planting in the intermountain region may be resumed.

The Cottonwood Nursery had an excellent soil but was operated under unfavorable climatic conditions. It was situated in the bottom of a broad canyon in the natural Douglas-fir zone. Snow fell to a depth of from 6 to 8 feet and sometimes lasted as late as May 25. Frosts were frequent throughout June, and "snow smothering" and frost injury were frequent. Early digging of the nursery stock was also difficult, and western yellow pine in particular could not be supplied so early as needed for planting. The nearest shipping point was 15 miles distant and hauling charges added $0.75 to $1 a thousand to the cost of the stock.

The Pocatello Nursery was located on a south slope in the juniper zone. It enjoyed relative immunity from "snow smothering" and frost injury. The shipping point, Pocatello, could be reached easily in early spring; but the soil of the nursery was a heavy clay loam, which was not only physically unsuited to conifers but also so constituted chemically that it induced chlorosis.

The Beaver Creek Nursery also had a heavy clay soil with a tendency to bake when dry. Snow conditions were intermediate between the Cottonwood and Pocatello Nurseries, for the ground was usually bare by April 15, and neither snow molding nor frost injury was so bad as at the Cottonwood Nursery. It was located 23 miles from the nearest shipping point, however, in a region of poor roads, especially during the spring shipping season. All were remote from sources of supply.

Any future nursery site in this region should be in the general locality where most of the planting work will be concentrated and within a few miles of a good shipping point and source of supply. It should have an elevation of approximately 6,000 feet, where the

snowfall is not excessive, and should be as nearly free from unusual frosts as possible. The soil should be a rich, moderately light sandy loam, free from coarse gravel and rock. The arable area would naturally depend on the amount of stock to be grown and the methods used. With the intensive methods in practice in the past, approximately 5 acres would be required for an annual output of 1,000,000 2–1 transplants. An ample water supply is essential.

NURSERY OPERATIONS.

The nursery practice at these nurseries indicates that standard methods will apply as well in this region as in the more humid localities where they were originated. The dryness of the air necessitates more watering and greater care and rapidity of work in all processes of transplanting, packing, etc., which involve exposure of roots to the air. Germination of seed with thorough watering is about as found elsewhere, averaging as follows:

Species	Germination period
Engelmann spruce	21 to 28 days.
Norway spruce	21 to 28 days.
Blue spruce	21 to 28 days.
Lodgepole pine	25 to 30 days.
Western yellow pine (Utah)	25 to 30 days.
Western yellow pine (Idaho)	25 to 45 days.
Douglas fir	25 to 45 days.

After germination the seedbeds require careful watering to keep the developing seedlings from drying and to bring on the germination of lagging seeds. Even in this dry region it is inadvisable to try to force the last seeds to germinate as it is likely to bring about losses from "damping off". Established seedlings require a thorough watering but once in 8 to 10 days. After August 1 all water is withheld to insure proper hardening before frosts occur.

The degree of shade is a matter that has to be determined for each site, and accordingly little can be said on that point for future guidance. It is worth knowing, however, that lodgepole pine and western yellow pine were grown successfully at the Cottonwood Nursery without any shade. Douglas fir and all of the spruces required shade during the first season and throve better when shaded during the second and third seasons. Experiments for the purpose of determining the optimum amount of shade for Engelmann spruce and Douglas fir gave results indicating that for the former species 50 per cent or possibly 75 per cent is optimum and half shade is sufficient for the latter.

First year seed beds were shaded from the time germination began; or if the weather was excessively hot, from the time the seed was sown until cool weather set in about September 1. In earlier years shade was furnished by means of a woven 4-foot wire and lath fencing, supported on a permanent framework by posts 8 feet above the ground. However, in 1919, the greater portion of the framework was torn down and replaced by low shade frames. The most satisfactory method of shading tried at the Cottonwood Nursery was a rolled 4-foot lath fencing of any desired length, supported by stakes 8 to 12 inches above the bed, on which were nailed 2 by 2 inch scantlings. The shades were placed in position and also removed by rolling them along on top of the scantlings, being very readily shifted at small expense.

The open-trench method of transplanting was used very successfully. (Pl. II, fig. 2.) The object of transplanting is the production of planting stock which is most likely to survive in field planting, especially on adverse sites. Its principal effect is to retard height growth and to stimulate the development of the finer lateral feeding rootlets. (Figs. 3, 4, 5, and 6.) Such transplant stock is much more suitable for planting on adverse sites than seedling stock. Since conditions are relatively unfavorable on many of the planting sites in the intermountain region, it is evident that transplant stock must be used on the majority of such sites.

Where heavy snows lie long, as at the Cottonwood Nursery, winter mulching proves more of a detriment than a benefit. Mulching was given a thorough trial during the early years with hay, straw, and leaves; but the results were very unsatisfactory, because the loss from snow molding in winter and early spring was thereby greatly increased.

PROTECTION FROM DISEASES AND INJURIES.

As already noted, the three old nurseries of this region were disadvantageously located in some respects. Some of the difficulties and injuries that had to be contended with were the direct results of the locations and would not assume very much importance in a better natural site. Other difficulties due to the dry air and intense sunlight are inherent in the climate and will always have to be guarded against. On the other hand, these factors minimize certain dangers that elsewhere are of great importance. For example, all of the coniferous species grown at the nurseries in this region are subject to damping-off, which, however, has never been of sufficient severity to warrant the use of the acid treatment that is being generally used in other regions(*6*). The nursery practice in this region has indicated that in this semiarid climate damping-off can be minimized by sowing seed of good quality about June 10, when an abundance of sunlight and daily light watering assure prompt and vigorous germination. During the period in which the seedlings are susceptible to this disease, just enough water is applied to keep them from suffering from drought. When excessive rainfall occurs during the critical period it is necessary to remove the shade frames to let in as much sun and air as possible.

Stem girdle, on the other hand, is a nursery injury which the climatic characteristics tend to accentuate rather than to relieve. Prior to 1918 this disease was one of the chief causes of loss to spruce transplant stock. The side of the trench against which the trees were transplanted was supposed to be perpendicular; but, as a matter of fact, it always had a slight slope, depending on the direction in which the trench was opened. Since all rows run east and west, the slope of the transplanted trees of necessity had to be either to the north or south. During 1916 and 1917 a large number of both Engelmann spruce and Norway spruce (*Picea excelsa*) were transplanted, about half leaning to the north and the other half to the south. It was later found that on all beds where the trees leaned to the north the loss was approximately 25 per cent greater than among those leaning to the south. This abnormal loss on trees leaning to the north was found to be due to stem girdle caused by excessive heating of the surrounding surface soil(*4*). Trees leaning toward the south shaded the soil surrounding the base by their own

tops, consequently the disease was not present among such trees. This conclusion was later verified by a series of experiments. Since the cause of the trouble first became known, all transplants have been given a slight slope to the south, and only normal losses have occurred, generally not to exceed 8 per cent.

Other troubles such as snow molding, frost injury, and chlorosis were due primarily to local peculiarities of the nursery site. Snow molding has been a problem in high-altitude nurseries for a long time in both Europe and America. If impossible to dispense with nurseries in such situations, a method developed at the Cottonwood Nursery can be used. Two logs at least 6 inches through are placed on each side of the bed, across which planks are laid so that they hold up the snow(*2*).

Chlorosis, or "yellowing" was the most serious problem encountered in the successful production of nursery stock of all the coniferous species raised at the Pocatello Nursery. With chlorosis were associated poor growth of roots, stems, and leaves, failure to form normal

FIG. 1.—Douglas fir transplants (3–2), the tops of which were severely injured by a late spring frost. Cottonwood Nursery, Utah.

terminal buds, and susceptibility to winter injury. Chlorosis was definitely corrected at the Pocatello Nursery by spraying with ferrous sulphate at 10-day intervals(*5*). A 1 per cent solution in amounts sufficient to wet the tops thoroughly proved the most satisfactory treatment, as stronger solutions ultimately caused chemical injury to practically all of the seedlings. The soils on which the conifers were decidedly chlorotic contained considerable amounts of carbonate, while the water at the Pocatello Nursery contained much calcium bicarbonate. This leads to the conclusion that the chlorosis was due chiefly to a lack of dissolved iron in the water of certain calcareous soils. Such a condition is probably infrequent but should call for caution in locating nurseries on such soils.

Frost damage and freezing are factors that have to be dealt with everywhere. These were exceptionally difficult to cope with at the Cottonwood and Beaver Creek nurseries, on account of their high elevation. At lower altitudes the danger is less, but in the case of Douglas fir the losses may be heavy. (Figs. 1 and 2.) Late spring

frosts are typical of the whole Rocky Mountain region and care must always be exercised to prevent excessive frost injury. The best means is to retard spring development as much as possible by the use of shade frames as soon as the buds begin to swell. This prolongs the period of hardiness. Nevertheless, very late severe freezes are not unknown, and hay and straw must be kept on hand to mulch the beds deeply in such contingencies(*3*).

Seed-eating rodents, including several species of mice, chipmunks, and ground squirrels, are a source of nursery losses of considerable magnitude throughout the West.

The white-footed mouse (*Peromyscus maniculatus artemi*) is the most common of the wild mice and doubtless the most destructive, being active throughout the year. It frequently invades buildings, doing considerable damage to stored forest-tree seed and grain. It will even dig up the newly-sown seed beds at night. The jumping mouse (*Zapus princeps*) is widely distributed, but the number found in any

FIG. 2.—Douglas fir transplants (3-2) protected from late spring frost by a mulch of timothy hay applied just prior to the occurrence of the frost, but the tops were injured by a previous spring frost. Cottonwood Nursery, Utah.

one place is not large and the damage is less extensive, although not negligible. Several species of meadow mice (*Microtus*) are found in fields and meadows, where they have regular runways. They are active throughout the year and under cover of the snow cut small seedlings. Chipmunks (*Eutamias*) are particularly troublesome, devouring and storing away considerable quantities of forest-tree seed. Ground squirrels (*Citellus*) are also destructive in eating off the newly germinated seedlings. Pocket gophers (*Thomomys*) excavate tunnels under the beds, depositing the excavated soil in mounds over the beds, and in winter destroy both seedlings and transplants.

The practice of screening against rodents was not considered practicable at the nurseries. The nursery grounds were thoroughly cleaned up, brush and tall weeds close to the seed-bed area were cut and burned, and piles of rubbish, lumber, and rocks moved away. In this way, many nests and hiding places were destroyed. Then by a systematic campaign of trapping and poisoning carried on at the

same time, they were soon so reduced in number that only a minimum of damage occurred. Poisoned baits recommended by the United States Biological Survey were frequently used.

Grasshoppers thrive best in semiarid regions and do most damage during several successive dry years. They do not prefer conifers, but eat both the leaves and young bark of nursery stock when other green foods are no longer available. At such times they may become so serious a menace as to require control measures. At the Pocatello Nursery these insects for two seasons required intensive control, which was undertaken during the early wingless period of the grasshopper's life, as the young ones are more susceptible to poisoning and are less nomadic before they can fly.

Maybeetle larvae, aphids, and birds have at times taken considerable toll at the different nurseries. These are general pests and their damage and methods of control are essentially no different in the intermountain region than elsewhere, although they are probably less destructive here and more easily controlled.

DISTRIBUTION OF PLANTING STOCK.

In case the planting stock should be needed for early planting at a lower altitude than the nursery, some artificial means of removing the snow was necessary. Its natural disappearance, which takes place about May 10, was hastened several weeks by sowing black soil over the surface at the rate of about 1 bushel per 1,000 square feet. (Pl. III, fig. 1.) Soil to be used for this purpose was obtained during the preceding summer when thoroughly dry, and was stored under cover.

Digging, grading, and bunching the stock intended for field use were done as soon as the soil had dried off sufficiently in the spring. The trees were lifted by means of a spade or spading fork thrust into the soil to a depth of 7 to 10 inches depending on the species and the size of the trees. One or more pickers followed the spade man, pulling up the trees, grading out all small, weak, or injured ones, counting and tying them loosely in bunches of 25 or 50, according to the size of the trees. If the shipment was to be made promptly the bunches were only temporarily heeled-in; otherwise, they were placed in the storage shed. Under favorable conditions, the work of digging, bunching, grading, and heeling-in was done at the rate of 6,000 transplants per man per day.

Since most of the planting sites were located at high elevations and opened from two to four weeks later than the nursery, it was necessary to store the trees to keep them from growing until needed in the field. The floor of a frame shed was covered with a 10-inch layer of sand and gravelly soil in which the loosely tied bundles of trees were heeled-in as fast as taken out of the nursery. They were then covered with a 2-foot layer of snow from a near-by drift, with a 3-inch layer of sawdust on the top. After a storage period of 26 days, the trees were found to be in excellent condition, without any signs of growth.

The burlap method of packing stock for shipment was adopted subsequent to 1917, replacing the former method of packing the trees in wooden crates. (Pl. III, fig. 2.) The burlap roll is far more economical, and at the same time trees packed by this method with-

stand rough treatment in transit equally as well as those packed in crates. Wet sphagnum moss was used to keep the trees moist.

Table 4 gives the approximate average number of trees contained in a full-sized burlap roll, with the weights and rate of packing for various age classes of nursery stock.

TABLE 4.—*Average number of trees in a full-sized burlap roll, weights, and rate of packing for various age classes of nursery stock.*

Species.	Age class.[1]	Number per roll.	Average weight.		Rate of packing per day.	
			Per roll.	Per M.	1 man.	2 men (packer and helper).
		M.	*Pounds.*	*Pounds.*	*M.*	*M.*
Lodgepole pine	2–1	2.0	65	32.5	40	60
Western yellow pine	2–1	1.8	72	40	30	45
Engelmann spruce	2–2 3–1	1.5	75	50	25	40
Blue spruce	2–3	1.0	75	75	15	25

[1] The first figure in the "age class" column is the number of years the nursery stock was grown in the seed bed, and the second figure the number of years in the transplant bed.

The average cost of planting stock for the years 1915 to 1919, by age classes, for the principal species grown at the Cottonwood Nursery, is given in Table 5. On account of losses from snow-molding and frosts, which at that time were uncontrolled, the cost for Douglas fir of all age classes above the 1–0 class was far greater than for any of the other species.

TABLE 5.—*Average cost of tree production at the Cottonwood Nursery, 1915 to 1919, inclusive.*[1]

Class of stock.	Average cost per 1,000.					
	Engelmann spruce.	Blue spruce.	Norway spruce.	Lodgepole pine.	Western yellow pine.	Douglas fir.
1–0	$0.436	$0.49	$0.364	$0.48	$0.52	$0.53
2–0	.836	1.02	1.08	1.42	.84	4.22
3–0	1.21	1.48	2.09			22.42
2–1		6.05		6.49	4.77	
2–2		7.45				
2–3		10.86				
3–1	6.01	8.01	6.67			39.01
3–2	10.27		10.26			43.53

[1] These costs are exclusive of distribution charges, which amounted to approximately $2.50 per M, including overhead.

FIELD PLANTING.

PLANTING SITES AND NATIVE TIMBER TYPES.

In the mountains of the intermountain region there is a regular zonation of forest types, and in each zone there are characteristic differences in planting sites. The highest zone is typified by Engelmann spruce and alpine fir (*Abies lasiocarpa*). Below this, Douglas fir or white fir (*A. concolor*) usually predominates except where through the agency of fire lodgepole pine (in northern Utah, western

F-37080A

FIG. 1.—TRANSPLANT BEDS OF WESTERN YELLOW PINE ON WHICH BLACK SOIL WAS SOWED TO REMOVE THE SNOW TO FACILITATE THE EARLY SHIPMENT OF PLANTING STOCK FROM THE BEAVER CREEK NURSERY, UTAH

F-153352

FIG. 2.—TIGHTENING BALE OF ENGELMANN SPRUCE TRANSPLANTS. BALES IN RIGHT FOREGROUND READY FOR SHIPMENT TO PLANTING AREA. COTTONWOOD NURSERY, UTAH

F-20077A

FOUR 2-MAN CREWS PLANTING A NORTHERN ASPECT IN BIG COTTONWOOD CANYON, WASATCH NATIONAL FOREST, UTAH, USING THE SIDE-HOLE METHOD OF PLANTING

Wyoming, and Idaho) or aspen (*Populus tremuloides*) (in Utah and Nevada) has become dominant temporarily. Below the Douglas-fir zone comes western yellow pine in both central Idaho and southern Utah. In central Utah, however, north to the Snake River drainage, a brush belt takes the place of the western yellow pine type; and, where this species is lacking in Idaho and western Wyoming, either a grass type covers the lower mountain slopes or the Douglas-fir or the lodgepole-pine type extends directly to the sagebrush valleys or plains. In central Idaho, below the western yellow pine, is an open grassy type extending to the Snake River plains; while in central Utah, below the western yellow pine and oak-brush types, is a belt of piñon pine (*Pinus edulis*) and Utah juniper (*Juniperus utahensis*) which extends to the valley flats.

The chief areas in need of reforestation in the Engelmann-spruce type are old burns where recurring fires have completely removed the former forest cover. Through fire and erosion the rich soils of some of these areas have been rendered sterile; but those areas which have recently suffered from fires are among the easiest to reforest. These recent burns are still strewn with down timber, the mineral soil is exposed and there is neither serious erosion nor the difficult problem of dense grass or brush growth. Far less promising are the many large open areas covered with weeds and grass, usually dotted with clumps of trees. These have never been considered as planting sites and should not be so considered. European experience on similar sites has shown that the highest use of such land is for grazing.

In the Douglas-fir zone below the Engelmann-spruce type,where burns do not become so rapidly covered with dense grass and herbs and deep-rooted shrubby species are much more prevalent, older burns offer excellent planting sites. Indeed, some sites that are now brush-covered occupy burns so old that no direct evidence of them exists. In general, any brushy area at that elevation occupying normally forested slopes forms a satisfactory planting site.

The western yellow pine type offers few opportunities for planting, as burns are rare and not severe. Natural reproduction is generally taking place, except on sites too severe to be desirable for forest planting. The oak brush, however, although its altitudinal position is analogous to the western yellow pine zone, is mainly without forest growth. A great deal of planting has been done here, on the supposition that this belt was a potential western yellow pine site; but, while planting has been proved possible, more careful investigations have indicated that the oak-brush zone of central Utah possesses characteristics which will make it impossible for the western yellow pine to perpetuate itself naturally.

Below the western yellow pine and oak-brush belts, no planting sites can be considered on account of their severity. They support at best only open forests of piñon pine and Utah juniper.

METHODS OF PLANTING.

The general methods of planting management and organization in vogue throughout the country have been used in the intermountain region. These are well known and are described in detail by Toumey and by Tillotson (*8*, *9*).

Of the various methods of planting, only two—the center-hole and the side-hole—have been used in this region. The center-hole method was most frequently used in the earlier planting work, but was later replaced by the second method in which the soil is firmed on one side of the tree. It is possible to use narrower holes in the side-hole method; the roots are spread out rather than crowded to the center; and the planting is done more quickly. Also, the side-hole method has proved the best to use with relatively inexperienced labor. (Pl. IV.)

The relative advantages of these and various other methods of planting have not been exhaustively worked out, but there is a great mass of general information which shows that trees properly planted by either the center-hole or side-hole method have about equal chances of survival. The cone method is too expensive for the results secured. The slit method was made the subject of experimental comparison with the center-hole method on a planting site (Rock Creek, Targhee National Forest). The results to date, which indicate a considerable inferiority of the slit method, are shown in Table 6.

TABLE 6.—*Effect of method of planting upon survival and growth, Rock Creek planting area, Targhee National Forest, Idaho.*

Species.	Age class.	Per cent alive, 1921.		Growth, 1921.	
		Center-hole method.	Slit method.	Center-hole method.	Slit method.
				Inches.	*Inches.*
Lodgepole pine	2-1	38	36	1.6	1.5
Do	3-0	59	43	2.5	2.1
Douglas fir	2-1	22	6	1.0	1.2
Do	2-2	9	6	1.2	1.2

In general, care and thoroughness are more important than method. In 1916, six plantations were carefully made by forest officers upon areas which had been planted by common labor a few days before. In every case there was a higher survival on the plantations made by the forest officers, the difference averaging 16 per cent and ranging from 2 to 36 per cent. The advantage still persists when the extra cost of the more careful work is considered. In only one case was the cost per surviving tree lower with the cheaper but more careless labor. Careful planting by either the center-hole or side-hole methods gives all that can be desired.

NUMBER OF PLANTS PER ACRE.

Regular spacing of trees in planting in the intermountain region is usually undesirable and in many cases impossible. Protection from drought is of paramount importance on nearly all sites, and accordingly planting close to the edges of down logs and stumps on burns has proved much superior to planting in the open, while on brush lands the trees should be placed neither in the spaces between the clumps nor in the thick growth but on the northern peripheries of the clumps. Only in the case of aspen stands having slight undergrowth can even spacing be resorted to among the sites usually considered for planting. The trees should run about 1,000 to the acre, equivalent to a spacing of about 6 by 7 feet. On open brush lands,

this leads to rather crowded spacing on the edges of clumps, but high loss is to be expected in such places and the final result will not indicate too close spacing.

RESULTS OF FIELD PLANTING.

Because of its importance and character, western yellow pine has been planted much more commonly than any other species in the treeless brush belt. The successful forestation of this belt, as potential yellow-pine land, would be of great importance in the silvicultural management of the central Utah forests. A large proportion of the earlier forestation work has, however, been unsuccessful.

WESTERN YELLOW PINE.

Class of planting stock.—Aside from the factor of suitability of site, which is of the greatest importance, the age class of stock necessary for success on a given area should receive the most careful consideration in the intermountain region. In selecting western yellow pine for field planting, the relative size and development of fibrous roots is very essential, and therefore the age class of western yellow pine planting stock has been the subject of careful study in this region. The relative size of the classes studied is shown in Table 7.

TABLE 7.—*Comparison of different age classes of western yellow pine firsts.*

Age class.	Source of seed (forest).	Average diameter of stem at root collar.	Average length of top.	Average length of root.	Average weight of top.	Average weight of root.	Ratio of weight of root to weight of entire plant
		Inches.	*Inches.*	*Inches.*	*Grams.*	*Grams.*	*Per cent.*
1-2 (1917)[1]	Ashley	0.17	3.2	12.0	2.80	1.13	28.8
2-0 (1917)[1]	Salmon	.13	3.3	11.6	1.79	.54	23.2
2-1 (1917)[1]	Sevier, Ashley	.16	3.1	11.6	2.89	1.08	27.2
3-0 (1917)[1]	Sevier	.17	5.6	12.3	4.00	1.17	22.6
3-1 (1917)[1]	Boise	.18	5.4	11.8	4.66	2.24	32.5
2-1 (1919)	Salmon	.18	6.2	10.1	5.40	2.05	27.5
2-0 (1920)	do	.14	2.5	12.0	3.85	1.30	25.2
2-0 (1920)	Sevier	.11	2.2	9.1	1.49	.41	21.6
2-1 (1920)	Salmon	.13	4.0	11.2	4.32	2.21	33.8
2-1 (1920)	Sevier	.14	3.2	11.5	4.22	2.08	33.0
1-1-1 (1920)	do	.16	2.9	10.5	3.79	2.02	34.8

[1] Unavoidably air-dried for 30 days.

The best general criterion of stock suitable for field planting is the balance between the root and the top, which is most conveniently expressed by weight. But for the experienced nurseryman the actual appearance of the plant is the most satisfactory guide, for a root system that weighs heavy in proportion to the top may yet be composed mainly of large coarse roots with few lateral, fibrous rootlets. The best class of planting stock is that which has a small top and a large fibrous root system. Such a balance is essential in western yellow pine, which tends toward a less satisfactory development. A well-balanced transplant is especially necessary to develop for use on severe sites, such as those found in the intermountain region. A study of Figure 3 shows that, in both the Utah and Idaho forms of western yellow pine, the 2–1 stock is superior as far as relative root development is concerned. Two and three year seedling stock has satisfactory tops, but the root development is very poor; 1–2 and 2–2 stock is unsatisfactory because there is a tendency for the transplant to develop a decided tap root during the second year in the transplant bed.

Another factor of some importance is the percentage of good plantable stock which may be graded out as it is dug from the nursery beds. A special study of grading practice was made and arbitrary grades were established for the various age classes of western yellow pine. Table 8 shows the percentage of each grade for each age class studied.

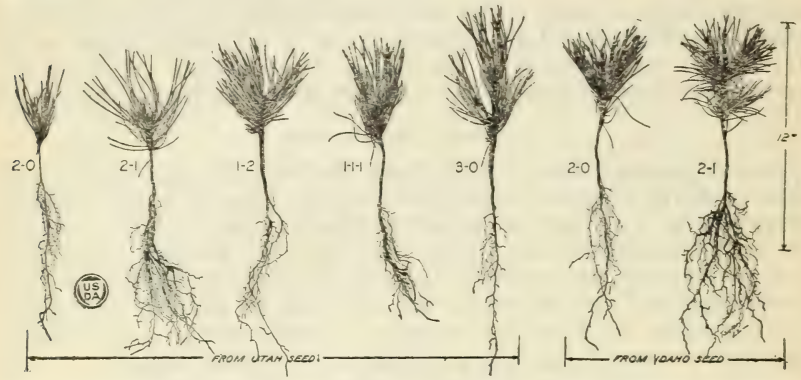

FIG. 3.—Development of western yellow-pine stock of different age classes grown in the Cottonwood Nursery, Wasatch National Forest, Utah

TABLE 8.—*Results of the grading of different age classes of western yellow pine nursery stock.*

Age class.	Grade.		
	Firsts.	Seconds.	Culls.
	Per cent.	*Per cent.*	*Per cent.*
2-0	32.5	48.7	18.8
3-0	1.1	9.4	89.5
1-2	46.6		53.4
2-1 (1917)	70.7		29.3
2-1 (1918) [1]	52.5		47.5
3-1	20.4		79.6
1-1-1	27.2		72.8
2-1-1	39.6		60.4
2-1-1 (2-1 firsts) [2]	56.0		44.0
2-1-1 (2-1 seconds) [2]	23.2		76.8

[1] This lot of stock was considerably below the average for 2-1 stock on account of having been injured in the transplant bed.

[2] Some of the 2-1 western yellow pine stock, graded into firsts and seconds and re-transplanted, gave these results when graded the following spring as 2-1-1 stock.

In the grading of seedling stock the firsts were stock which was considered suitable for field planting, while the seconds were considered suitable for transplanting but unsuitable for field planting. The culls were stock unsuitable for use either for field planting or for transplanting and were discarded. In grading this stock it was assumed that trees selected for field planting should have the proper balance between root and top. The necessary grading of 2–0 seedlings as illustrated in Table 8 adds from $1 to $1.50 a thousand to the cost of the 2–0 planting stock on account of the cost of the stock discarded, which makes it but little cheaper than 2–1 stock for field planting. The extremely low percentage of 3–0 stock suitable for field planting is due to the unbalanced top and root development, the very long coarse tap root, the almost complete absence of fibrous secondary laterals developed within 12 inches of the root collar, and

the large heavy top. The use of this class of stock for field planting is out of the question. If the first two grades, or 10.5 per cent, are considered for transplanting, the cost would prove excessive and the resulting transplant stock of very questionable utility.

The 1–2 stock shows up well in the transplant beds, but the root development is discouragingly meager. The roots have very few fibrous laterals and a dearth of root hairs. This stock does not show up well for transplant stock when compared with 2–1 transplants. There is the further disadvantage of transplanting 1–0 seedlings, especially the Rocky Mountain form of western yellow pine, which are too small to handle economically. The same objections hold for 1–1–1 stock. Furthermore, the second transplanting in the case of 1–1–1 and 2–1–1 stock does not have the same beneficial effect that the first transplanting has in stimulating favorable root development. The merits of the 2–1 class of stock are largely self-evident from the foregoing discussion, especially when corroborated by the survival data which follow.

Field tests of the different classes of stock used commonly in this district were made in three different localities. The essential results are shown in Table 9.

TABLE 9.—*Survival of various classes of stock.*

Locality.[1]	Age class.	Survival last examination.
Wasatch National Forest:		*Per cent.*
1. Big Cottonwood	2-1	30
	2-2	16
2. Big Cottonwood	2-1	34
	2-2	28
3. Big Cottonwood	2-1	27
	2-2	14
Cache National Forest:		
4. Mink Creek	2-0	22
	3-0	10
	1-2	11
	2-1	26
	2-2	14
5. Mink Creek	2-0	3
	3-0	3
	1-2	16
	2-1	35
6. Mink Creek	1-1	1
	2-1	7
Manti National Forest:		
7. Ephraim Canyon	2-1	33
	2-0	15
	1-2	18
	2-2	6
8. Ephraim Canyon	2-1	40
	2-0	43
	1-2	33
	3-0	3

[1] Details of plantations are given for the areas as numbered in Table 9, as follows:

1. Planted fall 1915 on sagebrush-ceanothus-oak brush-aspen area with a southern aspect, results shown for fifth year after planting.
2. Planted fall 1915 on ceanothus-oak brush area with a western aspect, results shown for fifth year after planting.
3. Planted spring 1916 on same area as preceding, results shown for fifth year after planting.
4. Planted in spring of 1916 on burned-over sagebrush land, results shown for fourth year after planting.
5. Planted spring of 1917 on same area as preceding, results shown for first year after planting, as all age classes were dead at the next examination.
6. Planted spring of 1917 on brushy northeast exposure coming back to bitterbrush (*Kunzia tridentata*) and snowberry (*Symphoricarpos sp.*).
7. Planted spring 1916 on open oak-brush site with western aspect. The plantation resulted ultimately in total failure for all age classes. Results shown are for first year.
8. Planted spring 1917 on oak-brush site with western aspect, more favorable than preceding. Results shown for third year.

In every case but the last 2–1 stock shows the best survival. Averaging all these results, it appears that if the survival of 2–1 stock is made the standard with a value of 100 for convenience, the survival of 2–0 stock will be 62, 2–2 stock 52, and 1–2 stock nearly the same, while 3–0, much poorer, is 16, and 1–1, poorest of all, with a value of 14. The cause of this difference is the better balance between the top and root in 2–1 stock than in any other. The tops are small and the root system large and fibrous. That this is the true explanation of the superiority is indicated not only by the data in Tables 7 and 8, but also by the experience gained in planting trees of different relative development but all belonging to the 2–1 age class.

In the spring of 1916 a record of one thousand 2–1 trees planted on five different sites was made, classifying both roots and tops as large, medium, and small. The results were as follows at the end of the first year:

Trees with large top and large root showed a 75 per cent survival; medium top and large root, 74 per cent; medium top and medium root, 63 per cent; small top and medium root, 59 per cent; small top and small root, 51 per cent; large top and medium root, 49 per cent; medium top and small root, 48 per cent; and large top and small root, 27 per cent.

After considering all of the factors involved in the determination of the age class of western yellow pine best adapted to the planting needs of the region, the evidence is unmistakably in favor of 2–1 stock, from the standpoints of the relative balance between top and root, the development of a compact fibrous system of absorbing rootlets, and the ultimate survival and subsequent development in the field.

Season of planting.—The period from 1911 to 1913 saw considerable fall planting on a rather large scale. In addition to western yellow pine, Douglas fir, Engelmann spruce, and a few exotic species were rather extensively planted; but the results were so unsatisfactory with regard to the species other than western yellow pine that the practice was discontinued in favor of spring planting. Fall planting of western yellow pine proved advantageous on southern exposures where the snow melts very early, because it enabled the trees to become established early in the spring while the nursery from which stock could be supplied was still under snow. However, the greater possibility of inclement weather accompanied by snows render all fall planting projects uncertain. Experiments were continued until the spring of 1920, the results of which are included in Table 10.

In comparing the 100-tree plots planted in the fall of 1915 with those planted in the spring of 1916 in Big Cottonwood Canyon, it will be seen that the former show the highest percentage of living trees and compare favorably in percentage of vigorous trees. On the Ephraim Canyon watershed all fall plantings were very unsuccessful; but it should be noted that none were made on open south slopes similar to those in Cottonwood Canyon. On the other hand, a comparison of the plantations established in the fall of 1919 with those planted the previous spring or in the spring of 1920 shows that, in practically every case, the spring plantings were superior to those made in the fall.

TABLE 10.—*Record of experimental plantations of western yellow pine in the intermountain region.*

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.[2]	Average height growth.[2]
No.[1]	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Ephraim Canyon Watershed, Manti National Forest, Utah:							*Per cent.*	*Inches.*
1	Oak, north slope	2-0	May, 1913	92	69	62	[3] 58	28	0.70
1	Do	2-0	Sept., 1913	0				0	
2	Do	2-1	May, 1916		67		25	21	.90
3	Do	2-1	May, 1919	88				78	.59
3	Do	2-1	do	91				85	.71
3	Do	2-1	May, 1918	92	79	64		29	.98
3	Do	2-1	May, 1920	71	53			27	.51
3	Do	2-1	do	86	60			34	.48
4	Oak, west slope	2-1	May, 1917	79		40	23	9	.85
4	Do	2-0	do	61		43		42	.95
4	Do	1-2	do	56		33		27	.57
4	Do	3-0	do	15		3		2	1.50
4	Do	2-1	May, 1918	75	48			45	.64
4	Oak, protected	2-1	Oct., 1916	5				0	
4	Oak, unprotected	2-1	do	5				0	
5	Oak, west slope	2-1	May, 1915	83	50		([4])	15	.84
6	Do	2-1	May, 1916	41				27	.21
6	Do	2-2	do	10				6	.07
6	Do	2-0	do	20				14	.50
6	Do	1-2	do	17				13	.30
7	Brush, permanent	2-1	Apr., 1916	58			30	21	.52
8	Oak-sage	2-1	do	35			7	6	.92
9	Do	2-1	May, 1916	64			24	23	1.06
10	Sage	2-1	May, 1917	40	25	23	22	14	.89
10	Do	2-1	May, 1918	74	68	60		12	.31
10	Cleared sage	2-1	May, 1917	64	52	47	46	37	2.58
10	Do	2-1	May, 1918	73	65	55		34	1.94
11	Manzanita	2-1	Apr., 1916	63	55		[5] 50	24	.42
11	Do	2-1	May, 1917	56		48	44	24	.32
11	Do	2-1	May, 1918	65	60	56		35	.65
12	Wild apple	2-1	May, 1917	62		47	41	19	.50
12	Do	2-1	May, 1918	82	51	51		10	.37
13	Serviceberry-oak	2-1	do	82	27			3	.07
4	Cleared oak	2-1	do	58	47			31	.25
14	Burn, Douglas fir	2-0	Sept., 1913	0				0	
14	Do	2-0	June, 1914	96	78	71	[6] 66	45	1.66
15	Aspen	2-0	May, 1913	99	80	66	[7] 62	33	1.00
16	Do	2-0	Sept., 1913					0	
15	Do	2-1	May, 1916	88	76	71	[8] 71	38	.98
17	Aspen, unthinned	2-1	June, 1917	73	47	38	29	1	.38
17	Aspen, ¼-thinned	2-1	do	81	80	78	74	46	.94
17	Aspen, ½-thinned	2-1	do	81	74	65	60	17	.74
17	Aspen, ¾-thinned	2-1	do	67	57	50	46	10	.66
17	Aspen, cleared	2-1	do	52	43	29	29	25	3.10
17	Snowberry	2-1	do	39	24	14		13	.62
18	Brush, temporary	2-0	June, 1913	92	41		([9])	8	1.08
	Salina Canyon Watershed, Fishlake National Forest, Utah:								
19	Brush, permanent	2-0	May, 1914	30	15			0	
	Payson Canyon Watershed, Uinta National Forest, Utah:								
20	Sagebrush	2-0	Apr., 1915	40	34			2	
20	Open	2-0	do	50	48			2	

[1] For full descriptions of sites, see paragraphs correspondingly numbered in the Appendix, page 51.
[2] From records at last examination.
[3] Observation three years later showed 42 per cent survival.
[4] Fifth year survival was 21 per cent.
[5] One per cent less the following year.
[6] Observations to seventh year showed about 3 per cent less annually, down to 56 per cent.
[7] Survival, sixth year, 49 per cent; seventh year 48 per cent.
[8] Four per cent less the following year.
[9] Next observation, in seventh year, showed 10 per cent only.

TABLE 10.—*Record of experimental plantations of western yellow pine in the intermountain region*—Continued.

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.	Average height growth.
No.	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Big Cottonwood, Canyon Watershed, Wasatch National Forest, Utah:							*Per cent.*	*Inches.*
21	Brush, permanent	2-1	Apr., 1918	73	44			39	0.20
21	Do	2-1	May, 1919	32	22			15	.40
21	Do	2-1	Oct., 1919	12				11	
21	Do	2-1	do	25				21	
21	Do	2-1	May, 1920	92				89	
21	Do	2-1	do	88				83	
21	Do	2-1	Oct., 1920						
21	Do	1-2	Oct., 1913	96	88	80	[10] 68	44	.90
21	Do	2-1	Oct., 1915	67	51	38	[8] 34	23	.90
21	Do	2-2	do	35	26	24	[8] 20	10	.70
22	Brush, temporary	2-1	May, 1919	13	10			7	.20
22	Do	2-1	Oct., 1919	35				19	
22	Do	2-1	May, 1920	91				65	
22	Do	2-1	May, 1919	53	45			28	.20
22	Do	2-1	do	23	20			9	
22	Do	2-1	Oct., 1919	35				18	
22	Do	2-1	May, 1920	85				71	
22	Do	2-1	Oct., 1915	68	54	48	[11] 40	32	1.00
22	Do	2-1	May, 1916	70	45	36	[12] 32	23	.60
22	Do	2-2	Oct., 1915	48	36	32	[10] 30	26	1.10
22	Do	2-2	May, 1916	47	31	21	[8] 18	30	1.10
	Beaver Creek Watershed, Wasatch National Forest, Utah:								
23	Oak brush	2-1	May, 1917	81	74	64	55	28	1.40
24	Cleared sagebrush	2-1	do	92	86	65	46	27	1.40
25	Sagebrush	2-1	do	79	77	57	40	22	.50
25	Do	2-0	Apr., 1915	54	38	36	11		1.10
	Lamb's Canyon, on Parley's Canyon Watershed, Wasatch National Forest, Utah:								
26	Oak brush	2-1	May, 1920	90	64			34	.24
26	Do	2-1	do	88	62			38	.77
	Mink Creek Watershed, Cache National Forest, Idaho:								
27	Sagebrush	2-1	May, 1917	0				0	
27	Do	2-1	do	7				0	
27	Do	2-0	do	3				0	
27	Do	3-0	do	3				0	
27	Do	1-2	do	16					
27	Do	2-1	do	35					
27	Do	2-1	do	7		1		0	
27	Do	2-1	do	61		8		0	
27	Do	1-2	Apr., 1916	62	54			28	
27	Do	1-2	do	36	20		11	2	
27	Do	2-1	do	80	56		26	7	
27	Do	2-2	do	58	40		14	2	
27	Do	2-0	do	69	50		22	2	
27	Do	1-2	do	58	26			21	
27	Do	2-0	do	64	47			30	
27	Do	2-0	do	66	36			22	
27	Do	3-0	do	44	25		10	2	
27	Do	1-2	do	77	68			46	
28	Aspen	2-1	Apr., 1915	67	[13]			14	
29	Brush, permanent	1-1	May, 1917	92		1		1	
29	Do	2-1	do	47		7		2	
30	Brush, temporary	2-1	do	88		81	78	68	1.30
30	Do	2-1	do	91		81	78	74	1.20
30	Do	2-1	Apr., 1918		75	66		56	1.80
	Rock Creek, Targhee National Forest, Idaho:								
31	Thin aspen, north slope	1-2	Oct., 1915	27				4	
31	Do	1-2	do	25					
31	Thin aspen, bench	1-2	do	2				0	
31	Do	1-2	do	3				0	

[8] Four per cent less than the following year.
[10] Two per cent less the following year.
[11] Six per cent less the following year.
[12] Five per cent less the following year.
[13] Burned over and plantation destroyed.

These apparently contradictory results are evidently caused by snow molding, a form of fungous injury which often causes serious losses during seasons of late melting of the winter snow. Snow molding is especially serious to fall-planted stock, because it has not become established before the beginning of the winter snows. The winter of 1915–16 had a normal amount of snow which disappeared during the latter part of April, therefore there was no loss from the snow molding fungi that winter, and the stock showed a high survival. During the winter of 1919–20, there was a heavy snowfall which did not melt until the latter part of May. By this time a large percentage of the stock planted the previous fall had been killed by the fungi, and this accounts for the great difference in survival in favor of the spring planting.

In summing up the results, there seems to be little difference between the results of fall and spring planting where snow does not lie too long and too deep. Where the plantations are made on south-facing slopes, the advantages of fall planting are especially marked; for here in addition to the early melting of the snow, spring planting is at a special disadvantage, owing to the drying out of the sites before stock can be secured from high-altitude nurseries and before mountain roads are generally open and passable. However, on many of the sites, because of the possibility of serious snow molding injury accompanying heavy snowfalls or late melting of the snow in the spring and the greater probability of inclement weather in the fall, early spring planting has generally proved more satisfactory.

Sites suitable for western yellow pine.—Extensive plantations have been made on the permanent brush lands of the Great Basin, on potential Douglas-fir sites on which a temporary cover of brush has come in following fires or other devastating agencies, and limitedly within the lower portion of the aspen type. The sites within the permanent brush lands include areas having a cover of oak brush (*Quercus utahensis*), serviceberry (*Amelanchier alnifolia*), manzanita (*Arctostaphylos pungens*), wild apple (*Peraphyllum ramosissimum*), snowberry (*Symphoricarpos oreophilus*), sagebrush (*Artemisia tridentata*), *Tetradymia canescens inermis*, or an association of two or more of these species. The temporary brush lands are for the most part characterized by snow brush (*Ceanothus velutinus*), chokecherry (*Prunus melanocarpa*), ninebark (*Opulaster malvaceus*), serviceberry (*Amelanchier alnifolia*), and myrtlebrush (*Pachystima myrsinites*). The planting of western yellow pine in the brush lands has been extensively investigated and fully discussed elsewhere.[2]

The majority of the experimental plantations were located in four general regions. The largest number were established in oak brush, sagebrush, manzanita, and wild-apple associations in the permanent brush type and under aspen and on Douglas-fir burns on the Ephraim Canyon watershed, Manti National Forest. Others were placed in permanent brush characterized by a mixture of sagebrush, oak brush, snowbrush, serviceberry, chokecherry, elderberry (*Sambucus caerulea*), and scattering curl-leaf mahogany (*Cercocarpus ledifolius*) and aspen, and on an area of temporary brush occupying a Douglas-fir burn on the Big Cottonwood water-

[2] Baker, F. S., and C. F. Korstian. Report in preparation.

shed. A number were also established in both sagebrush and oak brush on the Beaver Creek watershed on the Wasatch National Forest, and on three sites in the permanent brush type and one site in the temporary brush type on the Cache National Forest in southern Idaho.

On the Ephraim Canyon watershed the plantations were for the most part centered on a rather compact area where a number of the important sites found in the oak brush belt occur close together. This area is situated at an elevation of approximately 7,400 feet in the central part of the oak brush type. (Pl. V, fig. 1.) The mean annual precipitation is only about 13 inches, the greater part of which falls during the winter in the form of snow. The site becomes free of snow about April 15 in usual years, followed by occasional snows and rains until the middle of May, after which a period of drought usually extends with only infrequent small rains until the latter part of July or the early part of August. The plantations are therefore exposed soon after they are set out to very severe conditions of atmospheric and soil dryness. The area covers a small basin with a prevailing western exposure, of which the northern portion is characterized by a poor, shallow, and light-colored soil with a relatively small admixture of humus. To the south a darker clay loam is found. Most of the sites planted to western yellow pine were calcareous. The different planting areas are more specifically described in appendix.

Plantations were instituted on the Big Cottonwood Canyon watershed in 1913, 1915, 1916, 1918, 1919, and 1920. The Beaver Creek planting was done in 1915 and 1917. These areas are all between 7,300 and 7,600 feet in elevation.

The average rainfall in the vicinity of the Big Cottonwood plantations for the period from May 1 to October 31 is 11.47 inches; June and July have the lowest monthly average, being less than 1 inch for either month; and August has only 1.37 inches. Killing frosts frequently occur as late as June 15 and as early as September 1, while light frosts may be expected throughout the summer. The soils are of limestone, granodiorite, and quartz diorite origin, varying from a gravelly or sandy loam to a loam in texture, but are not excessively calcareous and receive more precipitation than the typical oak brush zone soils. That these sites are suitable for western yellow pine is furthermore indicated by the presence of a somewhat more moisture-loving series of shrubs than is common in the oak brush type on the Manti National Forest.

The Beaver Creek plots are located in a region of probably about the same rainfall. The oak brush is not so dense and tall as it is on the Manti National Forest; but soil moisture conditions are more favorable and the soil itself, being a rocky silty fine sandy loam, is more porous and less calcareous than on the Ephraim Canyon watershed. One of the most northern occurrences of western yellow pine in Utah is found on the Beaver Creek watershed near the plots. Furthermore, lodgepole pine is found on another site adjoining the plots.

The Mink Creek watershed on the Cache National Forest is characterized by a large, open, flat sagebrush area which was burned over in the fall of 1915, on which the sage, followed by a rank growth of geranium, is coming in again quite vigorously. Slopes of various

aspects are characterized by brushy species such as bitterbrush (*Kunzia tridentata*), snowberry (*Symphoricarpos oreophilus*), snow brush, serviceberry, myrtlebrush, chokecherry, and wild rose. (Pl. V, fig. 2.)

These areas lie between 5,500 and 6,000 feet elevation, near the center of the extensive area in northern Utah and southern Idaho in which native western yellow pine is not found. All of these areas receive scanty precipitation. The rainfall during the growing season averages about 12 inches. The days are warm and the nights cool during the growing season, only two and one-half months being free from killing frosts. The soil on the planting areas varies from a rather heavy brown silt loam on the sagebrush site to a gray to black silty very fine sandy loam on the other areas. The soil, derived from schist, diorite porphyry, limestone, and quartzite, is not excessively calcareous. While the majority of the plantations were installed in 1917, the sagebrush area was planted in 1916. An aspen area planted in the spring of 1915 was burned over the same fall. The area with temporary brush cover was planted in the spring of 1918.

Western yellow pine was planted to a limited extent on the Salina Canyon watershed of the Fishlake National Forest, the Payson Canyon watershed of the Uinta National Forest, in Lamb's Canyon on the Wasatch National Forest (all in Utah), and on the Rock Creek watershed of the Targhee National Forest in eastern Idaho. Table 10 gives a complete record of all of the experimental plantations of western yellow pine installed on the above-mentioned areas with sites and dates indicated, and with stock of the various age classes also shown. On most of these areas the plantations were composed of units of 100 trees each, although occasionally 200-tree units were used. In the earlier work up to and including the plantations installed in the spring of 1916 the trees were arranged in from 2 to 4 parallel rows, but subsequently square plots having 10 rows of 10 trees each were used in all the studies of planting sites.

Table 10 shows a considerable number of plantations which are now old enough to give reliable indications of the final results. On the Big Cottonwood watershed the plantation of the fall of 1913 in permanent brush shows up very much the best, probably because of exceptional circumstances (light winter snow) at the time of planting. At Beaver Creek results in oak-brush are also good. On the Mink Creek watershed two plantations in temporary brush show up very much the best, most of the other plantations being considerably less favorable.

A study of the first-year results in Table 10 shows that the poorest results in Ephraim Canyon are found in fall plantings and in spring plantings where poor age classes of stock were used. Sites which give subnormal survival are west-slope oak (1916 plantations), because the area planted that year was a very severe site with poor soil. Some of the sage and sage-oak plantations are very poor also, while the snowberry site is extremely unsatisfactory. These failures have occurred where soils are poor and heavy or where there has been excessive shallow-root competitions from sagebrush and snowberry. In Big Cottonwood Canyon, plantations have been made on fewer sites and the differences in success are due more to the variations in the wetness of different seasons. Certain plantations, both in permanent and temporary brush, and planted both in

the spring and the fall have proved very unsuccessful chiefly on this account. On Mink Creek, the 1917 plantations in burned sagebrush are very poor, on account of the dryness of the summer of that year. The 1916 plantations on the same site were moderately successful the first year but show excessive subsequent loss. The Rock Creek plantations are generally rather poor.

Growth naturally averages higher on the older plantations, where it normally increases from year to year. Current growth in excess of 1 inch a year is found in oak brush, where large 3–0 stock was used (with very low survival), also in oak sage, cleared sage, a Douglas-fir burn, one plantation under aspen, cleared aspen, and temporary brush. These sites are characterized by plenty of light coupled with soil conditions that run above the average. In Big Cottonwood Canyon, growth exceeds 1 inch per annum in three temporary brush plantations, while at Beaver Creek the best showing is in oak and cleared sagebrush. On the Mink Creek watershed, excellent growth is found on the same sites in temporary brush, where survival is best.

The oldest extensive plantation of which a record of both survival and height growth is available, was made in the fall of 1912 in the permanent brush type on the southern aspect opposite the Cottonwood Nursery. At the end of eight years this plantation showed 50 per cent of the trees alive with an average height of 13 inches. Another plantation made at the same time but on a less rocky site on the same aspect showed about the same survival and an average height of over 22 inches, the growth being about 3½ inches each year. The greatest proportion of the losses occurred during the first two years after planting. The plantations of 1919 and 1920 show plainly that the success of western yellow pine planting on either the permanent or the temporary brush lands depends quite largely on the amount of rainfall during the first season following planting. The season of 1919 was unusually dry, and consequently the mortality of the plantations of that year ranged from 47 to 77 per cent. On the other hand, the season of 1920 was favorable in available moisture and the mortality ranged from 8 to 15 per cent.

A study of all the western yellow pine plantations in the intermountain region leads to the following conclusions:

1. Western yellow pine plantations can be successfully established in the temporary brush type of the region, although results are frequently none too good because of the severity of this class of sites, as compared with those in other timber-producing regions of the West. Ample rainfall during the first season following planting is very frequently the one important factor which decides between success or failure. Although many of the temporary brush lands are potential Douglas-fir sites, western yellow pine, which is capable of withstanding the unfavorable site conditions better than Douglas fir, is more suitable for planting. If forest conditions were established, the site would undoubtedly become favorable for the natural invasion of Douglas fir.

2. The successful planting of western yellow pine on the permanent brush lands requires a careful weighing of the factors of cover, altitude, and moisture supply to secure the proper balance between survival and growth. Of the sites in the permanent brush

F-39963A

FIG. 1.—GENERAL VIEW OF OAK BRUSH PLANTING AREA IN EPHRAIM CANYON SHOWING A SAGEBRUSH FLAT AT THE LEFT. MANTI NATIONAL FOREST

F-153344

FIG. 2.—GENERAL VIEW OF MINK CREEK PLANTING AREA, CACHE NATIONAL FOREST, SOUTHERN IDAHO, SHOWING SAGEBRUSH LAND IN FOREGROUND, WESTERN YELLOW PINE PLANTED IN FURROWS AND ASPEN IN BACKGROUND, SUITABLE FOR THE PLANTING OF DOUGLAS FIR

F-39960A

FIG. 1.—LOWER EDGE OF ASPEN TYPE IN EPHRAIM CANYON, MANTI NATIONAL FOREST, UTAH. DOUGLAS FIR HAS BEEN PLANTED SUCCESSFULLY IN THE ASPEN IN THE FOREGROUND; OAK BRUSH TYPE IN THE CENTER

F-153345

FIG. 2.—PLANTING AREA NEAR COTTONWOOD NURSERY ON A WESTERN ASPECT COVERED WITH TEMPORARY BRUSH TYPE CHARACTERIZED BY CEANOTHUS VELUTINUS FOLLOWING LOGGING AND FIRE IN DOUGLAS FIR TYPE. WASATCH NATIONAL FOREST, UTAH

type in this region available for planting to western yellow pine the best are: (1) Open stands of brush where the trees may be planted on the north sides of rather isolated clumps of brush; (2) low brush that will shade the trees for only a few years; (3) dense stands of brush or aspen, cleared or heavily thinned within a few years of planting; (4) open areas at the higher elevations within the type; and (5) areas having favorable soil moisture conditions secured by clearing the native vegetation from otherwise suitable areas.

3. For field planting 2–1 is the best age class of stock to use.

4. The first establishment of plantations in the permanent brush type is most easily secured under rather dense cover. In the open it is naturally best on the moister sites.

5. Survival after the first year or two is best under cover, up to a certain optimum density which is heavier at low altitudes than at high. Survival as high as 78 per cent at the end of the fourth year has been attained. On the other hand, the most vigorous trees were found on moist sites in the open.

6. Growth is best on the moister sites in the open where there is plenty of available soil moisture and heat, and decreases with decreasing altitude, adverse soil conditions, slope, or exposure. The growth rate may in some cases reach 3 inches in height per annum the fourth year after planting.

DOUGLAS FIR.

Douglas fir occurs naturally thoughout the region and is usually found in mixture with white fir from the upper edge of the western yellow pine type or permanent brush zone to the lower edge of the Engelmann spruce type; while scattered trees are found in warmer situations well within the spruce and on cool sites, such as northern aspects down to the upper edge of the piñon-juniper type. Inasmuch as the aspen type frequently alternates with Douglas fir at the same elevations, it is natural that this species should have been planted under aspen at the outset.

Class of planting stock.—The general requirements as to the age class of Douglas fir stock most desirable for field planting are quite similar to those given above for western yellow pine. However, a few exceptions are worthy of note. In underplanting aspen it is necessary to use vigorous and sturdy transplants which will stand up straight during heavy snowfalls and during leaf falls in the autumn. Table 11 gives a comparison of 3–0, 2–2, 3–1, and 3–2 classes of Douglas fir stock.

TABLE 11.—*Comparison of age classes of Douglas fir stock.*

Age class.	Average diameter of stem at root collar.	Average length of top.	Average length of root.	Average weight of top.	Average weight of root.	Ratio of weight of root to weight of entire plant.
	Inches.	*Inches.*	*Inches.*	*Grams.*	*Grams.*	*Per cent.*
2–2	0.16	4.7	11.4	3.64	2.12	36.8
3–0	.08	6.0	11.4	1.62	.46	22.1
3–1	.14	6.6	11.5	3.82	2.54	39.9
3–2	.18	6.5	11.3	5.78	1.78	23.5

Two-year-old seedlings are, in most cases, too small to transplant satisfactorily. The 2–2 age class has been used extensively in field planting with the 2–1 class a fairly close second. The 2–1 class was found to be too small for general field use, and it will be seen from Table 12 that this age class has not always succeeded so well as larger-sized stock.

Transplants remaining in the transplant bed a second year were frequently subject to severe frost injury the second spring, owing to retarded growth caused by transplanting and a correspondingly

FIG. 4.—Development of Douglas fir stock of different age classes grown at the Cottonwood Nursery, Wasatch National Forest, Utah. The 2-2 and 3-2 stock was injured by at least two late spring frosts, while the 3-0 and 3-1 stock was uninjured, having been protected from frosts and snow-moulding fungi.

earlier start the second season. Three-year old seedlings are sufficiently large for transplanting (see fig. 4), and with one additional year's growth in the transplant bed make a very satisfactory class of planting stock. In the spring of 1919, it was possible to make a direct comparison of 3–1 and 3–2 stock planted under a moderate cover of aspen. Table 12 shows that in this instance the use of 3–1 stock resulted in a survival of 80 per cent as compared with a survival of 40 per cent for the 3–2 stock at the end of the second growing season.

Sites suitable for Douglas fir.—This species has been planted on four general classes of sites: (1) Under aspen of varying densities; (2) comparatively open recent Douglas fir burns; (3) temporary brush lands which are potential Douglas fir sites, from which the original forest cover has been removed either by early fires or by heavy cutting; (4) northern aspects in oak brush (Pl. VI, figs. 1 and 2). The results obtained on all of the experimental plantations are summarized in Table 12.

Many of the plantations of Douglas fir under aspen in Utah resulted unsatisfactorily, owing mainly to the use of small planting stock and to snow-molding. Snow-molding is serious in proportion to the length of time the snow lies on the ground in the spring and it therefore becomes more serious as altitude increases. This is especially true under aspen, which not only tends to retard snow melting to a certain extent, but which also forms a favorable substratum by its leaf fall for the development of the fungi. For this reason, results range all the way from entire failure in two years to 62 per cent survival after seven years. The former occurred at an elevation of 8,700 feet, the latter at 7,500 feet elevation. If altitude is correlated with average survival the second year, the indications are that at 7,500 feet elevation the survival would be normally 65 per cent, above which it would normally fall 10 per cent for every 250 feet increase in elevation. On the Mink Creek watershed in southern Idaho where snow molding has not been serious, a survival of as much as 95 per cent of vigorous trees at the end of the third year was obtained with 3–2 stock.

Losses on the open Douglas-fir burns were quite heavy, owing mainly to lack of sufficient shade to tide the trees over dry periods. In the oak brush zone survival has been generally poor and growth is below normal. However, a survival of 72 per cent has been secured with 3–2 stock at the end of three years on the more favorable northern aspects. This result is especially encouraging because the growth is practically as good as on any of the plantations. Frost injury is likely to be serious at the lower elevations, and for this reason it is desirable at the lower elevations to plant on steep northern aspects where spring budding is delayed as much as possible, and yet where cold air does not settle.

The shade of the oak brush cover and the moisture found on such sites are factors favorable also to summer survival; but in sagebrush the results are very poor, as the sites in the summer are drier than oak brush, while sagebrush is almost always found in flats and hollows subject to severe spring frosts.

The conclusions regarding the planting of Douglas fir in this region may be summarized as follows:

1. The aspen type in Utah, southern Idaho, and western Wyoming can be successfully underplanted with either 3–1, 3–2, or 3–0 Douglas fir stock, preferably the first-age class.[3]

[3] In order that the emphasis placed upon 3–1 stock may not be misconstrued, it is necessary to recall what has already been said, and shown in Figures 1, 2, and 4, regarding the susceptibility of Douglas fir to frost injury. It was not possible to grow good Douglas fir nursery stock until the frost injury and snow-molding problems had been solved. The available 3–2 stock was in most cases severely injured by at least one severe freeze, making it somewhat inferior to uninjured 3–1 stock. General nursery experience in this region as well as the writers' studies, all point to the superiority of 3–1 stock.

TABLE 12.—*Record of experimental plantations of Douglas fir in the intermountain region.*

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.[2]	Average height growth.[2]
No.[1]	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Ephriam Canyon watershed, Manti National Forest, Utah:							*Per cent.*	*Inches.*
15	Aspen	2-2	May, 1913	91	75	70	[3] 70	52	1.00
18	Brush, temporary	2-2	June, 1913	39	7		[4]	3	1.48
32	Dense aspen	2-2	do	48					.27
32	Do	2-1	June, 1914	30					
32	Aspen, ¾ density	2-2	June, 1913	34					.55
32	Do	2-1	June, 1914	22					
32	Aspen, ½ density	2-2	June, 1913	31					.28
32	Do	2-1	June, 1914	23					
32	Aspen, ¼ density	2-2	June, 1913	29					
32	Do	2-1	June, 1914	0				0	
32	Cleared aspen	2-2	June, 1913	20					
32	Do	2-1	June, 1914	0				0	
17	Dense aspen	2-2	June, 1917	60	35	32	32	19	1.03
17	Do	2-2	May, 1918	77	67	64		28	.11
17	Aspen, ¾ density	2-2	June, 1917	55	35	31	30	25	1.48
17	Do	2-2	May, 1918	77	70	69		62	1.46
17	Aspen, ½ density	2-2	June, 1917	61	53	52	50	34	1.36
17	Do	2-2	May, 1918	78	58	56		24	1.35
17	Aspen, ¼ density	2-2	June, 1917	44	29	27	25	16	1.58
17	Do	2-2	May, 1918	78	61	54		9	.79
17	Cleared aspen	2-2	June, 1917	18	9	8		5	.62
17	Do	2-2	May, 1918	50	25	24		11	.88
17	Dense aspen	3-2	June, 1917	76		52		44	1.14
17	Aspen, ¾ density	3-2	May, 1918	60				36	
17	Dense aspen	3-0	June, 1917	62		21		13	.55
16	Do	2-2	Sept. 1913	47	41	34	[5] 32	23	1.02
33	Do	2-2	Oct., 1914	30	21	18	[6]	4	.62
15	Do	2-2	May, 1916	75	56		53	36	.96
34	Do	2-2	do	61	50		45	38	1.03
35	Do	2-2	June, 1917	62	24	8		2	.91
36	Do	2-1	Sept., 1913	0				0	
17	Do	2-2	Oct., 1916	0				0	
37	Burn, Engelmann spruce	2-2	June, 1913	39					.75
37	Do	2-2	Sept., 1913	0				0	
14	Burn, Douglas fir	2-2	do	20	19	16	[7] 16	10	.97
14	Do	2-2	June, 1914	17	13	10	[8] 10	4	.33
14	Do	2-2	Oct., 1914	9	8	[8] 6		4	.78
38	Open	2-2	do	17	7		[9]	1	.55
39	Sagebrush	2-2	June, 1917	19	4	4		3	.70
40	Do	2-2	May, 1915	58	38	22		13	.53
41	Manzanita	2-2	June, 1917	17	4		[10]	4	
42	White fir	2-2	May, 1916	19			18	9	.57
43	Oak brush, north slope	2-2	Apr., 1916				18	18	.88
44	Do	2-2	May, 1917	41	21	13		12	.29
44	Do	3-2	May, 1918	95	75	72		60	.89
44	Do	3-2	May, 1919	83	56			21	.50
44	Do	3-2	May, 1920	64				31	.19
	Big Cottonwood Canyon watershed, Wasatch National Forest, Utah:								
45	Aspen	2-1	May, 1915	63	62	60	[11] 59	49	1.00
46	Grass	2-1	do	36	13	1			
22	Brush, temporary	2-2	May, 1918	58	32	24		18	1.00
45	Aspen	2-2	do	70	45	33		20	1.10
45	Do	2-2	do	94	69	51		38	1.30
22	Brush, temporary	3-2	May, 1919	5	4			1	.70
45	Aspen	3-1	do	89	80			16	.10
45	Do	3-2	do	59	40			4	.10

[1] For full description of sites, see paragraphs correspondingly numbered in the Appendix, page 51.
[2] From records of last examination.
[3] Seventh year survival, 62 per cent.
[4] Seventh year survival, 3 per cent.
[5] Fall off in survival about 2 per cent annually thereafter down to 26 per cent in seventh year.
[6] Seventh year survival, 5 per cent.
[7] Two per cent less two years later.
[8] No loss two years later.
[9] Only 1 per cent survival in fifth year.
[10] Fifth year survival, 16 per cent.
[11] Sixth year survival, 53 per cent.

TABLE 12.—*Record of experimental plantations of Douglas fir in the intermountain region*—Continued.

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.	Average height growth.
No.	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Lamb's Canyon watershed, Wasatch National Forest, Utah:							*Per cent.*	*Inches.*
47	Oak brush	3-2	May, 1920	66	39			24	
	Beaver Creek watershed, Wasatch National Forest, Utah:								
48	Aspen	2-2	Apr., 1915	58	34			20	
	Mink Creek watershed, Cache National Forest, Idaho:								
30	Brush, temporary	3-2	Apr., 1918		96	94		88	1.40
30	Do	2-1	May, 1917	82		36		10	
30	Do	2-1	do	78		54		24	
49	Aspen	2-1	do	84		48		10	
49	Do	2-2	do	88		53		15	
49	Do	2-1	do	78		25		7	
49	Do	3-0	do	89		61		12	
49	Do	2-0	do	94		56		11	
49	Do	3-2	do	97		74	74	59	1.10
49	Do	2-1	do	84		60		34	
49	Do	2-1	do	80		64		48	
49	Do	2½-0	do	86		68		20	
49	Do	3-0	Apr., 1918		89	88		72	
49	Do	3-2	do		95	95		95	
	Rock Creek watershed, Targhee National Forest, Idaho:								
50	Aspen, bench	2-1	June, 1917	34					
50	Aspen, north slope	2-1	Oct., 1915	50	35		[12]	10	1.10
50	Aspen, bench	2-1	do	1					
50	Aspen, north slope	2-2	do	37			[13]	8	1.20
50	Aspen, bench	2-2	do	25					
	Darby Canyon watershed, Targhee, National Forest, Wyo.:								
51	Aspen	2-1	June, 1917	76			24	4	.30

[12] Observation in fifth year showed 14 per cent survival.
[13] Observation in fifth year showed 8 per cent survival.

2. In Utah, underplanting with Douglas fir may be done successfully in the lower half of the aspen zone (below an altitude of 8,300 feet), the success increasing as the altitude decreases, owing mainly to the smaller losses from snow-molding. Good results may be secured under dense aspen where the light intensity is as low as 0.2 that of normal sunlight. (Pl. VII, fig. 1.)

3. Planting under dense aspen cover above an altitude of 8,300 feet in Utah is accompanied by uncertain results due primarily to snow molding.

4. Plantations in the open escape much of the heavy winter loss, but summer losses are considerably greater and satisfactory survival is difficult to secure except where the trees are planted on the north sides of bushes or down logs.

5. In the oak-brush zone winter loss is distinctly secondary to summer drought and frost injury, both of which increase with a decrease in altitude. These losses are reduced by planting under cover on northern aspects.

6. Flat, open, grass or sage covered areas where the trees must enter into competition with established vegetation for moisture

should not be considered as planting sites, as Douglas fir does not flourish in full sunlight except where soil moisture is exceptionally good.

7. The optimum planting sites for Douglas fir in Utah are old fir burns just above the brush belt, which have grown up to aspen of moderate density; old fir burns on steep northern exposures strewn with down logs or grown up to open stands of brush; and moist sites in the aspen-oak brush tension zone on slopes which have good cover and free air drainage.

ENGELMANN SPRUCE.

Engelmann spruce is native to the region, being found in Utah on steep northern exposures from 7,500 feet upward to the highest peaks, 10,000 feet or more in altitude. Its optimum development occurs on

FIG. 5.—Development of Engelmann spruce stock of different age classes grown in the Cottonwood Nursery, Wasatch National Forest, Utah.

moist, cool sites between 8,500 and 9,500 feet. Even here it seldom forms extensive stands on flats or southern exposures, but in these places appears as scattered individual trees or in clumps with limber pine (*Pinus flexilis*) and aspen. Alpine fir is a constant associate of Engelmann spruce throughout the type.

Classes of planting stock.—Four age classes of Engelmann spruce have been considered from time to time as having possibilities in field planting. These are 2–2, 3–0, 3–1, and 3–2, a comparison of which is shown in Table 13. 2–1 stock is entirely too small for field use, besides being too small to transplant satisfactorily when 2 years old. 2–2 stock is also objectionable because of the latter fact. Under normal conditions 3-year-old seedlings have reached a suitable size to be transplanted and yet do not have oversized tops. However, this class of stock is distinctly lacking in fibrous root development, as may be seen from Figure 5. With one additional year in the transplant bed an excellent balance between root and top is usually developed. An abnormally short growing season the first year in

the transplant bed sometimes makes 3–2 stock more desirable than 3–1 stock. From Table 13 it may also be seen that although in normal seasons 3–1 stock is preferable, 3–2 stock can be satisfactory.

TABLE 13.—*Comparison of age classes of Engelmann spruce stock.*

Age class.	Source of seed (national forest).	Average diameter of stem at root collar.	Average length of top.	Average length of root.	Average weight of top.	Average weight of root.	Ratio of weight of root to weight of entire plant.
		Inches.	*Inches.*	*Inches.*	*Grams.*	*Grams.*	*Per cent.*
2–2 (1919)	Pecos	0.20	7.5	11.6	13.22	3.54	21.1
3–1 (1919)	do	.16	5.9	9.9	6.96	2.98	30.0
3–2 (1920)	Gunnison	.20	5.6	11.9	8.44	4.98	37.1
3–0 (1921)	Wasatch	.08	3.4	9.7	1.46	.65	30.8
5–0 (1921)	Gunnison	.14	6.8	9.6	4.65	1.11	19.3
3–1 (1921)	Routt	.11	3.8	9.2	2.08	1.73	45.4
3–2 (1921)	Wasatch	.17	5.2	13.0	6.40	3.52	35.5

Sites suitable for Engelmann spruce.—This species has been planted principally in the natural spruce zone. However, a few plantations have been made outside, and therefore the altitude of these tests ranges from 7,400 to 10,000 feet. The majority of the plantations were confined to old burns in the spruce zone either strewn with logs, bare, or grown up to grass or underbrush, and to aspen stands both with and without a dense undergrowth of shrubs and herbaceous plants.

The survival in the plantations and percentage of vigorous trees at the last examination are given in Table 14. The differences in the survival on the different sites are worthy of note. An old burn having an open brush cover and down logs scattered over it had a survival of 84 per cent at the end of the fourth year. Two plantations on old log-strewn burns had survivals of 59 and 47 per cent at the end of the fourth year. There was an almost complete survival of those trees which were planted on the north side of logs, stumps, or bushes, while most of those without protection were dead. An adjacent plantation in a dense stand of brush gave poorer results, a survival of 24 per cent with only 17 per cent of vigorous trees at the end of the fourth year. Poorer results were secured under aspen, but this site is undoubtedly better adapted to Douglas fir than to Engelmann spruce.

TABLE 14.—*Record of experimental plantations of Engelmann spruce in the intermountain region.*

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.[2]	Average height growth.[2]
No.[1]	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Ephraim Canyon watershed, Manti National Forest, Utah:							*Per cent.*	*Inches.*
32	Dense aspen	2-2	June, 1913	95	82	79	[3] 74	17	0.7
32	Do	3-1	June, 1917	84	49	25		13	.4
32	Aspen, ¾-density	2-2	June, 1913	93	72	60	[4] 47	16	1.0
32	Do	3-1	June, 1917	83	67	61		52	.7
32	Aspen, ½-density	2-2	June, 1913	84	53	46	[5] 34	4	1.9
32	Do	3-1	June, 1917	49	13			13	
32	Aspen, ¼-density	2-2	June, 1913	88	43	31	[6] 21		
32	Do	3-1	June, 1917	50	15			13	
32	Cleared aspen	2-2	June, 1913	75	22	16	[7] 1		
32	Do	3-1	June, 1917	23	5			5	
52	Heavy aspen	3-1	...do	76					
52	Light aspen	3-1	...do	30					
52	Open aspen	3-1	...do	90			10		
37	Burn, grassy	2-2	June, 1913	84	46	38	[8] 25	10	1.4
53	Burn, open	3-1	June, 1917	99	95	81	84	67	1.2
	Big Cottonwood watershed, Wasatch National Forest, Utah:								
54	Aspen, northeast slope	3-1	June, 1917	77	50	50	39	26	.8
55	Do	3-1	...do	84	46	40	37	30	.5
55	Do	3-0	...do	82	51	47	43	33	.5
55	Do	3-1	...do	99	90	89	86	79	.7
56	Do	2-2	June, 1919	97	60			33	.6
56	Do	3-1	...do	98	85			63	.4
56	Do	3-1	...do	76	58			26	.1
56	Do	3-2	May, 1920	87				85	
56	Do	3-1	...do	100				100	
57	Aspen, west slope	2-1	May, 1918	83	29	14		6	.3
58	Burn, log-strewn	3-1	June, 1917	83	78	68	59	50	.6
59	Do	3-1	...do	74	62	51	47	39	.6
60	Burn, brushy	3-1	...do	54	36	27	24	17	

[1] For full description of sites, see paragraphs numbered correspondingly in Appendix, page 51.
[2] From record at last examination.
[3] Survival, fifth year, 61 per cent; sixth year, 27 per cent; seventh year, 24 per cent.
[4] Survival, fifth year, 29 per cent; sixth year, 23 per cent; seventh year, 16 per cent.
[5] Survival, fifth year, 18 per cent; sixth and seventh years, 4 per cent.
[6] The following year, 11 per cent survival, and the sixth year only 2 per cent.
[7] This survival maintained for two years.
[8] Observation in seventh year showed 12 per cent survival.

Excellent results were obtained on the Big Cottonwood watershed by planting good 3–1 stock under aspen of moderate density with little undergrowth. Survivals of 100, 99, and 98 per cent at the end of first year and 86 per cent at end of fourth year, with vigorous tree percentages of 100, 79, and 63, respectively, are very encouraging. On the other hand, survivals at the end of fourth year of 37, 39, and (with 3–0 stock) 43 per cent, and 30, 26, and 33 percentages of vigorous trees, respectively, were obtained in stands of aspen of moderate density where shrubs and herbaceous plants were sufficiently dense to smother the spruce transplants.

A study of the plantations listed in Table 14 leads to the following conclusions:

Recent burns on north slopes in the spruce zone can be successfully reforested with 3–1 Engelmann spruce, especially if protected by down logs, stumps, and open brush. (Pl. VII, Fig. 2.)

Northern aspects above an altitude of 7,400 feet covered with aspen of medium density but without dense underbrush and herbaceous plants are also favorable sites for the planting of 3–1 or 3–2 Engelmann spruce. This species may be established on warmer sites than where it is found naturally, provided there is a dense cover, and the survival will vary directly with the amount of shade.

F-152774

FIG. 1.—A SUCCESSFUL PLANTATION OF DOUGLAS FIR UNDER DENSE COVER NEAR THE LOWER LIMIT OF THE ASPEN TYPE, EPHRAIM CANYON, MANTI NATIONAL FOREST, UTAH

F-36707A

FIG. 2.—AN ENGELMANN SPRUCE BURN. SUCH AREAS MAY BE PLANTED SUCCESSFULLY WITH ENGELMANN SPRUCE BY PLACING THE TREES IN THE PROTECTION OF THE FALLEN SNAGS. MANTI NATIONAL FOREST, UTAH

Dense stands of brush, which offer keen competition with the spruce for the supply of available soil moisture, are undesirable planting sites.

Old burns bearing a dense cover of grass or other shallow-rooted vegetation are even more unfavorable planting sites, because they lack shade as well as sufficient available soil moisture.

LODGEPOLE PINE.

Class of planting stock.—As has been emphasized in the discussion of other species, the age class of stock is an important factor in the success of a plantation. Table 15 gives a comparison of various age classes of lodgepole pine stock which have been considered as possibilities for field planting. In this comparison the 2–1 stock shows the best balance between root and top. As has been noted with all of the preceding species, seedling stock is unsuitable for field planting both on account of its relatively poor development and its small size. The 1–2 class of stock is considered unsuitable for at least two reasons: (1) 1-year old seedlings are too small to transplant economically, and (2) the top development is entirely out of proportion to root development when left in the transplant bed a second year, because of an excessive lateral development of the side branches in addition to the increased terminal growth. A careful grading was made of these three age classes of stock into two grades, "firsts" and "culls," with the result that 2–0 stock showed 34. 9 per cent firsts and 65.1 per cent culls; 2–1 stock, 70.7 per cent firsts and 29.3 per cent culls; and 1–2 stock, 53.5 per cent firsts and 46.5 per cent culls.

TABLE 15.—*Comparison of age classes of first-grade lodgepole pine firsts.*

Age class.	Source of seed (national forest).	Average diameter of stem at root collar.	Average length of top.	Average length of root.	Average weight of top.	Average weight of root.	Ratio of weight of root to weight of entire plant.
		Inches.	*Inches.*	*Inches.*	*Grams.*	*Grams.*	*Per cent.*
1–2 (1917)	Wyoming	0. 21	5. 0	10. 9	13. 60	3. 85	22. 1
2–0 (1917)	do	.12	2. 3	7. 8	3. 60	1. 10	23. 4
2–1 (1917)	do	.18	4. 2	10. 1	7. 20	3. 60	33. 3
2–1 (1920)	do	.14	5. 4	11. 0	4. 23	1. 43	25. 3

The firsts were stock which was considered suitable for field planting on the basis of size, vigor, and relative balance between root and top. The culls were plants considered undesirable for the best results in field planting. In the 2–1 class the culls were mostly due to the small size of the tops. In the 1–2 class culling was due mainly to an unsatisfactory balance between top and root, while with the 2–0 class the small size of tops caused a heavy culling in addition to that due to an unsatisfactory balance between root and top. It is, therefore, evident that the 2–1 class is the most desirable age of lodgepole pine stock to use for field planting. Table 16 also bears out the superiority of this age class, although the difference between 2–1 stock and the other age classes is not quite so striking with lodgepole as with western yellow pine, a fact attributable to the generally better-developed root system of lodgepole pine.

TABLE 16.—*Record of experimental plantations of lodgepole pine in the intermountain region.*

Site.		Planting record.		Percentage of survival in years.				Vigorous trees.[2]	Average height growth.[2]
No.[1]	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Ephraim canyon watershed, Manti National Forest, Utah:							*Per cent.*	*Inches.*
10	Sagebrush	2-1	May, 1917	60		39		35	1.38
44	Oak brush	2-1	...do	69	48	48		46	1.33
44	Do	2-1	May, 1918		80			74	.68
18	Brush, temporary	2-0	June, 1913	76	51	51	[3] 45	23	1.35
14	Burn, Douglas fir	2-1	Oct., 1914	23	17	13	[4] 11	5	.75
14	Do	2-1	May, 1916	68	38	27	22	17	.66
53	Burn, Engelmann spruce	2-1	June, 1918	31	20	17		9	.99
53	Do	2-1	...do	84	60	54		29	1.10
53	Do	2-1	June, 1916	75				38	.56
53	Do	2-1	...do	77				17	.33
61	Do	2-0	June, 1913	39			[5]	5	1.23
33	Aspen	2-1	Oct., 1914	53	43	34	[4] 26	23	.72
33	Do	2-1	June, 1916	87	76	60	[6] 51	37	1.86
41	Manzanita	2-1	May, 1916	79	68	65	[4] 64	55	1.19
	Big Cottonwood Canyon watershed, Wasatch National Forest, Utah:								
22	Brush, temporary	2-1	May, 1918	72	47	38		28	1.3
55	Aspen	2-1	...do	97	93	88		80	1.6
55	Do	2-1	...do	96	80	73		68	2.3
22	Brush, temporary	2-1	May, 1919	23	20			10	.4
22	Do	2-1	May, 1920	95				91	
56	Aspen	2-1	May, 1919	93	74			46	.5
56	Do	2-1	May, 1920	95				91	
62	Open	2-1	...do	54				38	
56	Aspen	2-1	...do	93				90	
56	Do	2-1	June, 1919	59	53			41	.4
	Beaver Creek watershed, Wasatch National Forest, Utah:								
63	Sagebrush	2-1	May, 1917	71	65	53	45	22	
63	Cleared sagebrush	2-1	...do	92	90	68	50	30	
64	Aspen	2-1	...do	100	100	97	94	77	
64	Do	1-2	...do	94	92	83	80	68	
64	Do	2-1	...do	78	75	73	68	62	
64	Do	2-0	...do	87	86	75	70	53	
65	Sagebrush	2-0	April, 1915	24	22			2	
65	Do	2-1	...do	14	13			1	
66	Aspen	2-1	...do		84		[7]	44	
67	Do	3-0	June, 1916	46				5	
67	Do	3.0	...do	80				44	
	Montpelier Canyon watershed, Caribou National Forest, Idaho:								
68	Sagebrush	2-1	May, 1916	56				24	
69	Aspen	2-1	...do	99				81	
	Mink Creek watershed, Cache National Forest, Idaho:								
70	Sagebrush, burned	2-1	May, 1917	23					
70	Do	2-1	...do	66		41			
70	Do	2-1	April, 1916	90	60			33	
	Rock Creek watershed, Targhee National Forest, Idaho:								
71	Open, bench	2-1	June, 1917	39			2	2	2.6
71	Aspen, bench	2-1	...do	77			36	34	2.1
71	Aspen, north slope	2-1	...do	77				59	
71	Do	2-1	Oct., 1915	59	54		37	36	1.6
71	Aspen, bench	2-1	...do	11	3		1	1	5.0
71	Aspen, north slope	3-0	...do	70	64		51	51	2.3
71	Aspen, bench	3-0	...do	11	5			5	
	Darby Canyon watershed, Targhee National Forest, Wyo.:								
72	Open	2-1	June, 1917	97			63	62	2.1
73	Aspen	2-1	...do	97			63	38	1.1
73	Do	2-1	...do	100			14	7	.9
73	Do	2-1	May, 1916	95	84		38	32	.8
74	Burn, Douglas fir	2-1	...do	90	53			40	
74	Do	2-1	...do	86	55			39	

[1] For full description of site, see paragraphs numbered correspondingly in the Appendix, page 51.
[2] From record at last examination.
[3] Later survival record; sixth year, 38 per cent; seventh year, 29 per cent.
[4] Approximately this same percentage the following year.
[5] In seventh year, 9 per cent survival.
[6] In fifth year, 42 per cent survival.
[7] Observation in sixth year showed 54 percent survival.

Sites suitable for lodgepole pine.—This species has been planted extensively throughout the region, both within and outside of its natural range. In eastern Idaho and western Wyoming it was planted in aspen, in the open, and on Douglas fir burns similar to those upon which lodgepole pine has come in naturally as a temporary type following fire. In Utah plantings were made more than 100 miles outside of the natural range, on different kinds of brush lands, under aspen, in the open, and on Douglas fir and Engelmann spruce burns. One of the tallest and best-looking plantations in the region is one which was established in the fall of 1910 on the Big Cottonwood Canyon watershed. The trees, although very small when planted, were about 4 feet high 10 years later and were growing at the rate of 6 inches or more per season, which is a very good record for this region. The survival in the majority of the plantations was also very good.

Table 16 summarizes the results of experimental plantations of lodgepole pine in Utah, eastern Idaho, and western Wyoming, on which definite records are available. From the results obtained it would appear that this species offers as good or even better possibilities for reforesting many of the Douglas fir, lodgepole pine, and possibly some of the adverse Engelmann spruce burns, than any other species tested, for the following reasons: (1) The plantations show a lower mortality and a larger percentage of vigorous trees than those of any other species; (2) the trees are frost hardy and practically immune from snow-molding injury; and (3) it makes a more rapid growth than the other species.

The best lodgepole pine planting sites are found on northern, eastern, or western exposures and in the order of their favorability are: (1) Medium to thin aspen, (2) open brush, and (3) dense brush. Subsequent growth is always best in the open.

The survival of lodgepole pine is not markedly different in any altitude, from the oak brush to the upper spruce zones (7,500 to 10,000 feet). At the lower elevations survival is best under a good cover of oak brush, at intermediate elevations under a light cover of aspen, and at the higher altitudes apparently in the open. It is interesting to note, however, that in the sagebrush type the trees showed a higher survival and a larger percentage of vigorous trees on land from which the sagebrush had been cleared, than when planted among the sage bushes. This is due to the elimination, by clearing the land, of the root competition for the meager supply of available soil moisture. This method offers relatively little promise of application on an extensive scale, owing to the high cost.

NORWAY SPRUCE.

Norway spruce, native to northern Europe as well as to the mountains of central Europe, has been planted in the eastern United States with some success. This species was tested on practically all sites where Engelmann spruce has been planted, from the oak-brush zone to the middle of the Engelmann spruce zone. In most cases similar stock of both species was planted concurrently by the same planting crew. Table 17 gives a summary of the results obtained with Norway spruce. In comparing the results obtained with these

species, Engelmann spruce in every case but one shows a much higher survival and a larger percentage of vigorous trees than Norway spruce. In some cases the differences are as much as 30 to 55 per cent.

Loss due to snow molding was heavy in many of the plantations under aspen in Utah. Norway spruce is considerably more susceptible to snow molding, even in field plantations, than Engelmann spruce.

TABLE 17.—*Record of experimental plantations of Norway spruce in the intermountain region.*

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.[2]	Average height growth.[2]
No.[1]	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Ephraim Canyon watershed, Manti National Forest, Utah:							*Per cent.*	*Inches.*
36	Aspen	2-1	June, 1916	67	31			13	0.62
35	Do	2-1	May, 1916	82			13	7	.75
15	Do	2-1	May, 1913	94	93	93	[3] 86	63	1.04
15	Do	2-1	May, 1916	74	60	50	50	47	.90
17	Dense aspen	2-1	June, 1917	93	77	75	46	13	.68
17	Aspen, ¾ density	2-1	...do	84	76	68	67	50	1.14
17	Aspen, ½ density	2-1	...do	67	60	55	41	16	1.02
17	Aspen, ¼ density	2-1	...do	55	43	32	17	4	.95
17	Cleared aspen	2-1	...do	34	25	11	10	8	2.61
75	Aspen-chokecherry	2-1	May, 1916	67			23	15	
76	Manzanita-aspen	2-1	...do	93	85	79	[4] 68	38	.65
77	Open	2-1	...do	30				23	.60
18	Brush, temporary	2-1	June, 1913	81	53	45	[5] 35	13	1.33
37	Burn, Engelmann spruce	2-1	...do	78					1.00
37	Do	2-0	Sept., 1913	6				0	
3	Oak brush	2-1	May, 1916	62				49	.94
1	Do	2-1	May, 1917	68	51	41		40	1.40
	Salina Canyon watershed, Fishlake National Forest, Utah:								
78	Aspen	2-1	May, 1916	72				57	
79	Oak brush	2-1	...do	70				54	
	South Fork of Provo River watershed, Uinta National Forest, Utah:								
80	Aspen	2-1	...do	72				64	
80	Do	2-1	...do	59				44	
80	Sagebrush	2-1	...do	22				8	
80	Do	2-1	...do	21				4	
	Big Cottonwood Canyon watershed, Wasatch National Forest, Utah:								
22	Brush, temporary	2-2	June, 1917	83	67	49	26	17	.8
81	Dense aspen	2-2	...do	81	11	6		4	
82	Aspen	2-2	May, 1918	83	55	31		11	.7
82	Do	3-1	June, 1919	79	29			12	.3
83	Do	2-1	May, 1916	71	40	26	22	16	.6
83	Do	3-1	June, 1919	35	25			9	
	Beaver Creek watershed, Wasatch National Forest, Utah:								
84	Aspen	2-1	June, 1916	28				19	
84	Do	2-1	...do	65				52	
84	Do	2-1	...do	53				46	
	Mink Creek watershed, Cache National Forest, Idaho:								
85	Brush, permanent	2-1	May, 1917	4				0	
86	Aspen	2-1	...do	0				0	
87	Aspen	2-1	Apr., 1916	44				33	

[1] For full description of sites see paragraphs numbered correspondingly in the appendix, page 51.
[2] From record at last examination.
[3] By seventh year percentage was 68.
[4] Six per cent less the following year.
[5] Observation three years later showed 13 per cent.

TABLE 17.—*Record of experimental plantation of Norway spruce in the intermountain region*—Continued.

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.	Average height growth.
No.	Description.	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Rock Creek watershed, Targhee National Forest, Idaho:							*Per cent.*	*Inches.*
88	Aspen, north slope	2-1	Oct., 1915		12				
88	Do	2-1	---do		3			0	
88	Aspen, bench	2-1	---do		1			0	
88	Do	2-1	---do		0			0	
	Darby Canyon watershed, Targhee National Forest, Wyo.:								
89	Open spruce flat	2-1	May, 1916	19				5	
90	Do	2-1	---do	60	34		22	14	.8
91	Aspen	2-1	---do	87	78			53	
92	Sagebrush	2-1	---do	61	52			36	
	Montpelier Canyon watershed, Caribou National Forest, Idaho:								
-----	Aspen	2-1	---do	49				30	
-----	Sage	2-1	---do	56				12	

Like Engelmann spruce, Norway spruce shows the need of shade in its establishment. Indeed, its tolerance extends well into early life, although in a well-established plantation the harmful effects of light are less pronounced. Growth is often secured under partially thinned stands of aspen, but establishment is as a rule more successful in unthinned stands.

Throughout the Wasatch Mountains the seasonal rainfall and temperatures are very different from those obtaining within the native range of Norway spruce in Europe. The oak-brush zone is entirely unsuited to the species on account of summer dryness and high temperatures, but it is worth noting that on two oak-brush plantations almost half of the trees were still alive and vigorous at the end of the fourth year after planting. Future behavior is problematical. It is possible that these spruce plantations may become decadent at middle age and the tops of the trees die, as has happened in certain of the Eastern States. In fact this tendency has already been noted in ornamental Norway spruce trees in this region.

Nowhere in the region has the exotic Norway spruce given promise of being more successful or valuable than the native conifers. In most cases it has proven far inferior to the native Engelmann spruce from the reforestation standpoint. The best sites for Norway spruce are also the best for Engelmann spruce, although the latter species will in almost every case not only show a higher survival but will outstrip Norway spruce in subsequent development.

BLUE SPRUCE.

Blue spruce (*Picea parryana*) is native in Utah between altitudes of 6,500 to 8,500 feet, principally in moist situations along streams and in canyon bottoms. It is evident from Table 18 that blue spruce can be planted on all moist soils at altitudes to which it is inherently adapted, except where there is dense aspen shade. Plantations of blue spruce under aspen show in their growth and appearance a very apparent lack of vigor due plainly to insufficient light. It is very evident that

blue spruce is much more intolerant than either Engelmann spruce or Norway spruce planted under similar conditions, and that it can not be planted very successfully under shade as dense as aspen of intermediate density. Although 3–1 stock was not available for field planting, it is probable that because of the similarity of blue spruce to the other two spruces grown in the region, this age class of stock would in most cases be somewhat more desirable than that used.

TABLE 18.—*Record of experimental plantations of miscellaneous species in the intermountain region.*

Site.		Planting record.		Percentage of survival by years.				Vigorous trees.[3]	Average height growth.[3]
No.[1]	Description.[2]	Age.	Date.	1st year.	2d year.	3d year.	4th year.		
	Blue Spruce:							*Per cent.*	*Inches.*
93	Aspen, A	2-2	Oct., 1914	68	57		(4)	15	0.92
36	Do	2-2	do	89	69	57	(5)	27	.63
94	Brush, A	2-2	do	81	35	17	(6)	2	.54
82	Aspen, B	2-2-1	May, 1920	100				100	
82	Do	2-2	June, 1919	90	82			49	
82	Do	2-2-1	May, 1920	90				88	
	Western white pine:								
22	Brush, temporary, B	1-2	June, 1917	69	43	33	29	13	.20
81	Aspen, B	3-1	May, 1919	65	32			10	
81	Do	4-1	May, 1920	76				59	
95	Do	2-2	Oct., 1912				(7)	48	.90
82	Do	3-1	June, 1919	20	12			5	
82	Do	4-1	May, 1920	81				60	
96	Aspen, C	3-0	June, 1916	50				18	
96	Thin aspen, C	3-0	do	48				17	
97	Douglas fir burn, slope, D	3-0	do	70	70		57	52	.80
97	Douglas fir burn, flat, D	3-0	May, 1916	45	31				
	Western larch:								
82	Aspen, B	2-0	May, 1915	26				10	
96	Thin aspen, C	2-1	June, 1916						
98	Thin aspen, E	2-1	Apr., 1916	4				11	
91	Douglas fir burn, D	2-1	June, 1916				21	20	1.80
	Jack pine:								
22	Brush, temporary, B	2-1	May, 1919	18					
81	Aspen, B	2-1	June, 1919	48	6			1	
99	Sagebrush, E	2-1	Apr., 1916	74	62		15	10	
	Austrian pine:								
1	Oak brush, A	2-0	May, 1913	91	40	40	37	17	.90
1	Do	2-0	Sept., 1913						
15	Aspen, A	2-0	May, 1913	95	40	39	29	9	.70
16	Do	2-0	Sept., 1913						
99	Sage, E	3-0	Apr., 1916	60	42		42	5	
100	Aspen, north slope, F	3-0	Oct., 1915		23				
100	Do	3-0	do		10				
100	Aspen, bench, F	3-0	do		6				
100	Do	3-0	do		1				
	Scotch pine:								
15	Aspen, A	2-1	May, 1913	96	63		61		1.35
16	Do	1-2	Sept., 1913	6		1		0	.50
18	Douglas fir burn, A	2-1	May, 1913	59	13		9		.71
14	Do	1-2	Sept., 1913	18		12			2.25
	Jeffrey pine:								
99	Sagebrush, E	1-2-1	Apr., 1916	32	32			6	
	Thin aspen, B	1-2	May, 1916				80	50	
	Oriental cedar (*Thuja orientalis*):								
99	Sagebrush, E	2-1	Apr., 1916	10				0	

[1] For full description of sites, see paragraphs numbered correspondingly in the Appendix, page 51.
[2] Capital letters below indicate watershed and national forest where site is located, as follows:
A—Ephraim Canyon, Manti National Forest.
B—Big Cottonwood Canyon, Wasatch Nation Forest.
C—Beaver Creek, Wasatch National Forest.
D—Darby Canyon, Targhee National Forest.
E—Mink Creek, Cache National Forest.
F—Rock Creek, Targhee National Forest.
[3] From record at last examination.
[4] In fifth year 15 per cent survival, all vigorous trees.
[5] Observation in fifth year showed 50 per cent.
[6] Only 5 per cent survived through fifth year.
[7] First observation in sixth year showed 53 per cent survival, nearly all vigorous trees.

As blue spruce has a relatively low commercial value and only fairly good reproduction throughout its limited range, its use in forest planting is therefore very restricted. It is, however, a very desirable shade and ornamental tree and it offers considerable promise for use as such. It has been planted on lawns throughout the intermountain region, and has grown splendidly where given plenty of water.

WESTERN WHITE PINE (*Pinus monticola*).

Although not native to the intermountain region, western white pine has been planted to a limited extent in Utah and eastern Idaho. The oldest successful plantation consists of 2–2 stock planted in 1912 in scattering aspen and open brush on the Big Cottonwood watershed, Wasatch National Forest. At the end of the eighth year this plantation showed a survival of 53.5 per cent, with 47.5 per cent vigorous, the average height of which is 13.4 inches. Table

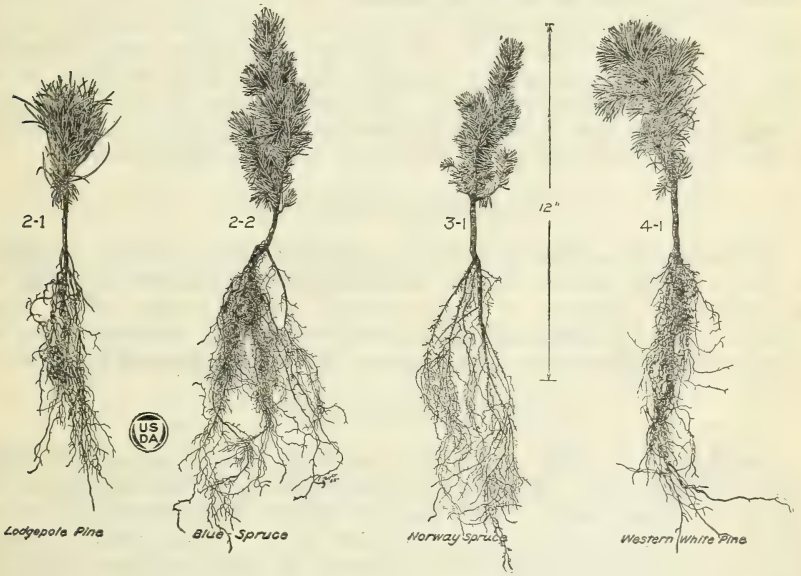

FIG. 6.—Typical development of lodgepole pine, blue spruce, Norway spruce, and western white pine grown in the Cottonwood Nursery, Wasatch National Forest, Utah.

18 shows that 3–0, 2–2, and 4–1 stock have been planted with success. Western white pine shows a natural tendency to develop a fibrous root system, even 3–0 stock showing a surprisingly good survival. In selecting the most desirable age class, the important essential is to secure a sufficiently large top at the time of transplanting so that it may be allowed to remain only one year in the transplant bed. From Figure 6 it can be seen that the 4–1 stock as grown at the Cottonwood Nursery was the most desirable class of stock planted. Although this species has shown promise for limited planting on the moister moderately open aspen-and-brush-covered sites, it is doubtful whether it should be used extensively on account of its relatively slow growth. This species is therefore not recommended for planting in this region.

WESTERN LARCH (*Larix occidentalis*).

Western larch is native to only the extreme northern part of the region. It was not planted experimentally within its natural range. Although an arboretum plantation of 2–2 stock made in the fall of 1912 averaged 32 inches tall, and had a survival of 50 per cent of vigorous trees eight years later, it can be seen from Table 18 that it has given very poor results in the other tests. Even though this species has shown very little frost or snow-molding injury, its use in Utah in preference to native conifers is still very questionable.

JACK PINE (*Pinus divaricata*).

Jack pine, although reaching its best development in the Lake States region, has been given a limited test in the intermountain region. The poor results shown in Table 18 for this species were mainly due to its failure to withstand the dry part of the growing season and to the high mortality caused by the snow-molding fungi. During one winter the mortality on one plantation was increased from 52 per cent caused by drought the preceding summer to 94 per cent due to snow molding. The results secured with jack pine clearly indicate that it is entirely unsuited to the climatic conditions of the region, and that it should not be used in reforestation.

AUSTRIAN PINE (*Pinus austriaca*).

Austrian pine, although native to central Europe, has been planted to some extent in this region, but the results as shown in Table 18 are generally inferior to those secured with western yellow pine (Table 10). Its outstanding characteristics and behavior were in many cases similar to the latter species but with a general inferiority.

SCOTCH PINE (*Pinus sylvestris*).

Scotch pine, a native of Europe, has been planted on a small scale, with some success. A plantation established in 1909 averaged 37 inches 11 years later. This species showed intolerance of shade, also difficulty in surviving on open dry sites. This species appears entirely frost-hardy and fairly immune to snow molding, but the heavy weight of the snow results in considerable injurious breakage. The growth of the surviving individuals in the open was above the average of all species tested, but was insufficient to recommend it for planting in the region.

OTHER CONIFERS.

Jeffrey pine (*Pinus jeffreyi*) was tested in two plantations, one of which was planted in sagebrush and resulted in a failure. The other one was successful. At the end of the fourth year, following planting, the living trees averaged 13.5 inches high. The plantation made no growth during the first year and very little during the second. Although Jeffrey pine showed no indications of frost or snow-molding injury, it has no other merits to recommend it for planting in the region in preference to native species.

A limited amount of Corsican pine (*Pinus laricio corsicana*) was planted, sufficiently to show that it was relatively immune to frost or snow-molding injury.

Oriental cedar (*Thuja orientalis*) resulted in a complete failure. Northern white cedar (*T. occidentalis*) was very susceptible to the snow-molding fungi, which resulted in its failure. Incense cedar (*Libocedrus decurrens*), in one test, showed relative immunity to snow molding, but possessed no other outstanding desirable features. Norway pine (*Pinus resinosa*) showed relatively poor results, while one-seed juniper (*Juniperus monosperma*) failed completely. After stratification over winter in sand and lying dormant in the seed bed throughout the following winter, Rocky Mountain juniper (*J. scopulorum*) germinated abundantly and was grown successfully. This species offers some promise for planting in the oak-brush zone for posts and fuel. White fir (*Abies concolor*) was grown successfully in the nursery, but is inferior to its associates for use in reforestation. Douglas fir, noble fir (*A. nobilis*), and silver fir (*A. amabilis*) 2–0 seedlings shipped from the Columbia River region were completely frozen while in the transplant bed.

European larch (*Larix europaea*) was easily planted, but the early fall frosts usually killed the new growth and so weakened the trees that the snow-molding fungi killed them all by the end of the first winter.

The following conifers, tried out to test their frost hardiness and adaptability to intermediate altitudes, were found to be entirely unsuited: Digger pine (*Pinus sabiniana*), sugar pine (*P. lambertiana*), and bigtree (*Sequoia gigantea*).

HARDWOODS.

A number of hardwood species were tested in the Cottonwood Nursery, but none were planted out in the field. At various times seed of the following species was sown: Boxelder (*Acer negundo*), hackberry (*Celtis occidentalis*), green ash (*Fraxinus lanceolata*), black locust (*Robinia pseudacacia*), Russian olive (*Eleagnus angustifolia*), and Siberian pea tree (*Caragana arborescens*). These species all germinated well and made good growth; but, with the exception of the last, all were severely injured by the early fall frosts before the new growth had become lignified. In most cases the trees were not killed outright the first season, but repeated killing back for several seasons either resulted in death or rendered them worthless as planting stock. Siberian pea tree, however, is entirely frost-hardy at the Cottonwood Nursery at an altitude of 7,500 feet, where several trees over 5 feet tall are annually producing seed.

CAUSES OF LOSS AND FAILURE AND METHODS OF PREVENTION.

UNFAVORABLE SITES.

Drought is responsible for nearly one-third of all the loss suffered in forest planting in the intermountain region. In the case of experimental plantations it has been the greatest single factor overshadowing all other causes. Many of the failures can be explained both on the basis of the selection of too arid sites and the disastrous effects of dry seasons. Administrative plantations in particular

have been strikingly affected by variations in rainfall from year to year. This is graphically shown in Figure 7. It must be remembered in connection with this chart that the chief plantings were in Utah, with western yellow pine, and usually at fairly low elevations. The general rising trend of the curve showing success is due to two causes: (1) Younger plantations are more likely to show success than older ones, other things being equal; and (2) better planting sites have been chosen during recent years and success has been actually better than before.

Figure 7 further shows that it is much more logical to attribute the successes to abnormally heavy rainfall than the failures to drought, as the dry years are much nearer the normal than such wet years as 1913 and 1914. It is evident that planting must be confined to sites having normally good moisture conditions in order to be successful. By planting at high elevations, better conditions in this regard can be obtained.

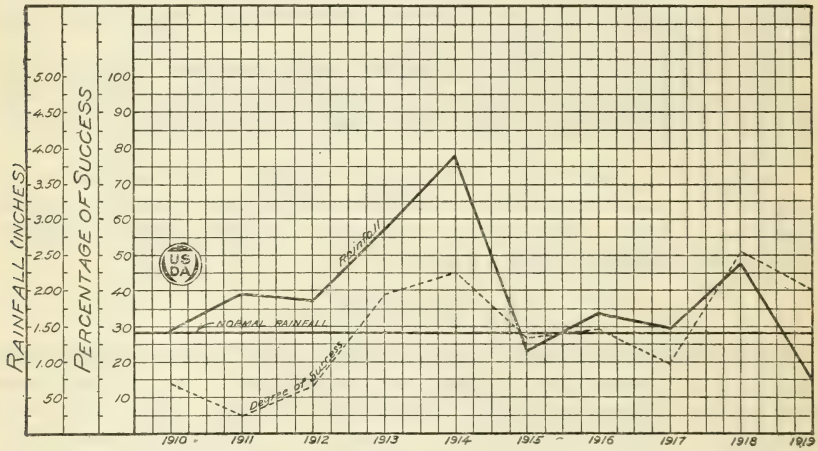

FIG. 7.—Rainfall for June and July (Utah State means) in relation to success of administrative plantations from 1910–1919, based on per cent of total area planted which was classed as successful in 1919.

In Ephraim Canyon on the Manti National Forest the rainfall at the mountain crest (10,000 feet) in June and July averages 2.28 inches (1915–1920); in the aspen or Douglas fir type (8,750 feet) it is virtually the same, 2.24 inches; in the oak-brush type (7,200 feet) it is 1.7 inches; while in the valley at the foot of the mountain (5,500 feet) it is 1.08 inches. Add to this the effect of the late melting snow at high elevations, and it is evident that soil-moisture conditions are decidedly superior in the upper region. On the more severe sites at low elevations, success can be expected only in exceptional years, the same being true of natural reproduction in these places.

The seasonal distribution of rainfall through the year is a factor that is believed to exert a profound influence upon the success of plantations in the intermountain region, and is probably the most powerful single factor in explaining the degree of failure experienced in this region in comparison with other regions equally arid when annual or even total summer rainfall is considered. It is impossible to show detailed rainfall figures for planting areas or even for general

planting regions to demonstrate this point clearly. In Table 19, however, an attempt has been made to indicate the probabilities of the case by applying a factor to the rainfall of certain valley stations with long records, which will indicate the rainfall at altitudes in that general region where planting is carried on (western yellow pine). This factor has been determined for each region by a careful study of rainfall increment with altitude, during the summer months for many United States Weather Bureau stations in each region. It is evident from this table that while Utah suffers from no such protracted period of drought as California, conditions at the time of planting and for the two months following are more severe in Utah, drying the plants before they become established.

TABLE 19.—*Rainfall interpolated by 10-day periods following the average date of planting western yellow pine in different parts of the West.*

Days after planting.	Rainfall.				
	Eastern Oregon, May 4.	Colorado, Apr. 7.	Western Montana, Apr. 20.	Northern California, May 1.	Utah, May 10.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1–10	0.76	0.75	0.61	1.09	0.69
11–20	1.04	.98	.66	.71	.64
21–30	1.63	.92	.90	.55	.50
31–40	.81	.81	.79	.38	.32
41–50	.71	.97	1.02	.35	.12
51–60	.42	1.08	1.07	.18	.18
61–70	.38	.66	.65		.22
71–80	.17	.30	.58		.15
81–90	.14	.47	.44		.20
91–100	.17	.55	.35		.25
101–110	.26	.68	.28		.32
111–120	.23	.57	.19		.32
121–130	.47	.50	.29	.16	.22
131–140	.40	.52	.63	.22	.33
141–150	.45	.38	.47	.87	.50
Total	8.04	10.14	8.93	4.51	4.96
Base station used	Baker City.	Denver.	Helena.	Red Bluff.	Salt Lake City.

The high mortality during the first growing season is due primarily to the inability of the roots to absorb moisture from the soil as rapidly as it is lost from the leaves through transpiration. This may be due to several factors within the plant such as (1) improper balance between root and top (over amount of transpiring surface), (2) failure of roots to develop new growth, (3) inability of the roots to grow fast enough to keep abreast of the falling water level, (4) wilting with a relatively high moisture content of the soil due to either a large amount of nonavailable moisture in the soil or a low concentration of the sap of the plant, or (5) a relatively high transpiration rate in comparison with the absorbing surface of the roots. On the other hand, with plant conditions satisfactory, high mortality may be due to unfavorable site factors such as (1) a deficiency of soil moisture due to the inability of the soil to conduct moisture to the roots as fast as they absorb it or a rapid reduction of moisture below the point of availability, (2) lack of shade inducing high transpiration, and (3) a physically impervious soil with low porosity or a high lime content which may induce chlorosis.

To avoid losses from summer drought, planting should be made at as high elevations as the adaptability of the species in question

will permit. The conspicuous success of western yellow pine on Douglas-fir burns may be cited as an example. In order to reduce first-year losses to a minimum, it is also desirable to use stock with (1) a well-balanced and extensive system of fibrous roots, (2) a tendency to develop a new and deep root growth quickly, (3) a relatively low transpiration rate in proportion to the absorption of moisture, and (4) a high resistance to wilting through high sap concentration.

These losses may also be guarded against by planting where there is a minimum amount of root competition with shallow-rooted vegetation already well established on the area. Disastrous results with western yellow pine on sagebrush sites have followed when this factor was ignored. Another common example is afforded by the complete failure of Engelmann spruce plantations on old spruce burns which have grown up to a dense stand of grass.

The density of the cover is charged with the failure of about 10 per cent of the administrative plantations and should always be considered in connection with the quality of the planting site. Although rarely responsible for the immediate extermination of plantations, the effect is cumulative and becomes successively more pronounced with the increasing age of the plantations. Since during the first season in the field much of the development of the plant is dependent upon stored food materials that were formed under the ideal conditions of the nursery, heavy cover at this time, shading the ground and thus preventing excessive water loss from the plant and the rapid drying out of the soil, rather encourages survival and growth. After the first year the plant is dependent upon its new habitat. Having become established by one year's field growth, sudden death is unlikely; but growth may become subnormal, with the result that the plant dwindles slowly away.

Snow-molding fungi are frequently dangerous on sites having too heavy cover and are often the direct cause of death. Then, too, species which are intolerant in youth naturally suffer most from too dense shade; western yellow pine, lodgepole pine, and blue spruce being frequently weakened and killed from this cause. Oak brush of maximum density and dense aspen are too dark for the general success of western yellow pine. Dense aspen leads also to failure of lodgepole pine and even when of only moderate density frequently reduces thrift. Blue spruce slowly fails under dense aspen and herbaceous cover (such as *Rudbeckia occidentalis*), and under all aspen stands with thick undergrowth.

It is evident that in order to insure the best success, sites selected for planting must have an ample supply of soil moisture during the growing season, proper shade, a fairly open, porous soil of high water supplying power and not chemically unfavorable.

RODENTS.

Rodents come next to unfavorable sites in responsibility for plantation failures, being charged with nearly one-fourth of the losses on administrative plantings. These animals, chiefly the snowshoe rabbit (*Lepus americanus*), gophers, and ground squirrels, are very destructive, particularly in new plantations established in localities distant from natural coniferous growth.

Rabbits.—A special study of snowshoe-rabbit injury to plantations and native conifers was made in this region, the results of which have appeared elsewhere (*1*). Cottontail rabbits (*Sylvilagus nuttalli*) also injure plantations, but less extensively than the snowshoe rabbits. When plantations are examined and tree after tree is found nibbled, eaten off, and dead, it is natural that failure should be charged to the snowshoe rabbit without considering very carefully whether the plantation would have succeeded if this injury had been avoided. The true effect of these rodents can be determined only by comparing results on protected and unprotected areas of the same site. Experiments along this line have not yet been completed. Analysis of results on plantations heavily attacked by the snowshoe rabbit, however, show that on favorable sites the death rate of trees attacked is only a few per cent higher than of those which have been untouched. On good sites the trees send out new shoots from adventitious buds again and again with remarkable vigor, and given a few years respite from the rodents, rapidly develop into good trees.

As a direct cause of mortality, rabbits are not so dangerous as at first appears, but they are one of the chief factors in retarding development of plantations and in keeping the trees small and weak. In new plantations the damage often occurs within a few days after planting, regardless of the season, the rabbits apparently relishing the novel food set out for them. In established plantations the damage is more often found in the spring after a long snowy winter, during which the rabbits found it difficult to secure sufficient food.

Pocket gophers.—While rabbit damage is of most importance, particularly throughout Utah and southern Idaho, pocket gophers (*Thomomys fuscipes*) are most destructive in certain localities of somewhat limited extent. These animals, by destroying and feeding upon the roots while burrowing underground, by covering small plants with mounds of soil successively thrown up at intervals of 5 to 10 feet, and by leaving burrows in which the air can circulate freely and dry the soil excessively, may entirely annihilate a plantation in a short time. They are found at practically all elevations and are active throughout the year, but do the most damage in winter, when they pack the soil in their runways between the snow and the surface of the ground. They appear less active in the spring than in the summer and fall. Gophers are more common on flats and in deep fine soil than on slopes or in rough stony soil. Plantations should never be established on areas where these rodents are common.

Ground squirrels.—The ground squirrel (*Citellus columbianus*), while less injurious than the pocket gopher, nevertheless injures plantations by burrowing alongside the trees, by covering them with soil, or by causing the roots to dry out. They also occasionally defoliate the trees and cut off the stems. Trapping with No. O or No. L steel traps is effective with both "burrow" and "surface" sets, but this method of control is not sufficiently rapid on large areas or where they are very abundant. Poisoning is the most effective method of control.

Rodents are undoubtedly credited with a greater amount of damage than they are actually responsible for, since in many cases dryness of the site alone would have caused these losses. Systematic trapping is practicable, but poisoning is the best means of combating

these pests, though not invariably effective. To be successful, the poisoned baits must be set when other food is scarce, and a much larger region than the contemplated planting area must be covered to take care of the animals that will wander in as soon as the newly planted food becomes available.

Porcupines.—Inasmuch as porcupines (*Erethizon epixanthus*), in addition to their other destructiveness, are given to gnawing coniferous saplings and poles, either killing them outright by girdling the trunk or seriously deforming them, they should not be permitted to increase in the forests. They may be trapped successfully; but, as in the case of other rodents, systematic poisoning is also a very effective method of control. The common method of poisoning is based upon the porcupine's well-known relish for salt. Brine-soaked planks are sprinkled with strychnine and fastened to trees above the reach of cattle, each bait board being sheltered from the weather by a small roof of untreated board above it.

SNOW MOLDING.

"Winterkilling" is charged upon the records with an amount of loss about equal to that from rodents and is a general term in reporting upon plantations used to include all kinds of losses, except those from rodents, that occur during the winter months. Winterkilling proper or loss due to excessive transpiration during periods when the soil is frozen is rare. At the intermediate and higher elevations, the snow comes so early and lies so continuously upon the ground that the soil seldom freezes during the entire winter. Losses under these conditions are more often the result of the heavy layer of deep snow and the relative warmth of the soil. The snow-molding fungi become very active and attack with frequently fatal results the newly planted trees. Douglas fir and the spruces are the species most frequently attacked, not only because they are usually planted at the higher elevations where snow lies longest, but because they are inherently more susceptible than the pines, as has been shown by observation of nursery stock (*2*). The heaviest damage is found where the plants are bent over into intimate contact with the soil and litter, the breeding ground of these weakly parasitic fungi. The best remedy is to remove 1 or 2 square feet of leaf litter when planting and to use only large vigorous stock that will stand firmly erect during the winter.

INEFFICIENCY IN PLANTING.

Poor work has been given as a frequent cause of failure, affecting approximately 5 per cent of the administrative plantations. Careful studies show that it is probably not a major factor but that it may contribute largely to failure, particularly of plantations on somewhat arid sites; since only by proper planting in deep holes can the rootlets reach the plentiful water supply of the deeper soil layers before the dry season overtakes them. Poor planting has been primarily due to overemphasis of speed and a desire to show a low cost per acre. The only remedy for this evil is a rigid insistence upon careful planting and the consideration of speed as a decidedly secondary factor.

QUALITY OF PLANTING STOCK.

The use of poor planting stock or too young trees has been given as the cause of a number of failures. This has been true particularly with Douglas fir. As stated above, this species is very susceptible to snow-molding fungi, especially when the tree is bent down into close contact with the litter. Hence, small and inferior stock is under a considerable handicap in this regard. The deficiencies of small stock have been so obvious that in recent years its use has been definitely abandoned and failures on this account practically eliminated.

GRAZING.

Grazing has been the cause of considerable loss in many plantations. As with rodents, however, grazing is rarely the immediate cause of death, at least on good sites. The trees are injured by the trampling of livestock and by browsing, but if given a chance will recover. One of the worst features of this form of injury is that it recurs year after year. A plantation that is placed in a location where heavy grazing occurs will in all probability be injured annually, for livestock have rather fixed habits in grazing particular areas. Most of the damage is done by cattle, because the extreme danger of sheep grazing has been so well recognized that plantations have not been made on sheep range. However, an experimental plantation on an Engelmann spruce burn heavily grazed by sheep, where the trees have been placed under the protection of down timber, has proved very successful. In general, it may be said that plantations should be closed to grazing, or otherwise protected, until the possibility of injury is passed.

These are the chief causes of failure of plantations. A few failures have been due to fires, excessive erosion, water-logged soils, and late spring frosts (especially in the case of Douglas fir). These are infrequent, however, and should be unimportant if sites are chosen with sufficient care.

PLANTING COSTS.

The average cost of planting per acre during 1913 to 1920, when most of the extensive planting was done in this region, was $18.13. Costs were lowest during the first year of that period, being approximately $12 per acre. The highest cost of $34.83 was reached in 1917. The average cost of planting per acre for the five years 1916–1920 was $28.55.

FUTURE OF ARTIFICIAL FORESTATION IN INTERMOUNTAIN REGION.

The future development of planting in the intermountain region is, in the last analysis, dependent upon general public policy. That much of the land within the national forests of the intermountain region would be serving its highest use if producing timber is incontrovertible. On the other hand, even in the forest-planting work of the Federal Government, the value of such an activity as reforestation can not be considered entirely apart from the cost.

At the present time, there are in other regions great areas in need of reforestation where the cost of planting is low, survival is good, and growth is rapid. Under such conditions, planting is a paying

investment in every sense of the word. The Government will recover its original investment with a good rate of interest, while the public will benefit through the production of valuable timber and ideal watershed protection.

It is obviously the present duty of the Government to expend the money appropriated for forest planting where the best returns are to be had, in those regions where timber can be most rapidly and easily grown. There are really no areas in the intermountain region falling clearly in this category, for in the few cases where results would undoubtedly be satisfactory from a timber production standpoint, as on high-altitude burns, the cost would be excessive on account of the inaccessibility and small size of the areas, and the high overhead expenses. Therefore, it is evident that general planting in the intermountain region will be deferred until other regions giving better returns are fully stocked, unless the value of forest growth on watersheds is shown to be sufficiently high for planting to be done with this prime object in view.

Forecasting very far into the future is dangerous. For example, the cost of planting trees is almost entirely an investment of labor, while the value of the final crop is due to supply and demand in the lumber markets. It is quite possible for one of these to vary independently of the other. Any factor tending to increase the difference between the two, giving a larger margin of profit to forest growing, will tend to throw the limit of economically plantable areas farther and farther toward the poorer sites. As soon as this economic process goes far enough the better sites of the intermountain region should be planted on the basis of commercial timber values alone.

It is impossible to reforest mountain areas for commercial timber production without receiving in addition the indirect benefits of watershed protection; and the reverse is also generally true, for the two benefits are virtually inseparable. It is therefore not strictly correct to speak of forest planting for commercial returns and for watershed protection as two separate and distinct activities. When, however, the monetary return from the forest crop fails to pay expenses and a fair rate of interest on the investment it must be considered that plantations made under such conditions are primarily for watershed protection.

In the intermountain region, especially the Great Basin, watershed protection and water conservation through the equalization of the flow of streams are the primary objects to be achieved, while timber production on a commercial scale is secondary, and will undoubtedly remain so for a relatively long period of years. The permanent wealth of Utah and southern Idaho depends upon the agricultural production of the valleys. While dry farming can be practiced in some localities, agriculture is primarily dependent upon irrigation water, derived almost entirely from watersheds within the national forests. Agricultural investigations are teaching how to use this water to the best advantage, and are putting a premium upon late water and a well-sustained flow; all of which has its effect upon the management of watersheds and points more and more clearly to the monetary value of water conservation in the mountains, as well as to its necessity.

Coniferous timber cover is the ideal protection for watersheds. On the lower mountain slopes, summer precipitation is light, and the

snow disappears slowly in the early spring so that erosion and stream-flow problems are of secondary importance. Here a brush cover of good density is a satisfactory protection, and here also the establishment of a satisfactory coniferous cover would prove most difficult. With increasing altitude, summer storms become more violent, the snow banks are deeper and melt more rapidly in the longer days of early summer. This later water is of the most value to irrigation. At high altitudes, therefore, especially within the Engelmann spruce zone, coniferous cover becomes of great value, not so much as a soil binder but as a means of reducing the rapidity of snow melting and thus retarding run-off. Fortunately this is the very region where artificial reforestation is most successful and where growth is fairly rapid. The inauguration of such work depends primarily upon the demonstration of its true monetary value, which has been very difficult to determine.

Such are the general conditions that will determine the future resumption of forest planting in this region. Whatever the particular conditions may be, the results of earlier planting work as shown in this bulletin point unmistakably to the fact that problems in this semiarid region are difficult indeed, and that general forest planting which is not preceded by careful investigation and experimentation on the contemplated planting sites is uncertain, if not predestined to failure from the outset. The work already done has shown something of the general favorability of the different classes of sites for the different species.

Future forest planting will probably be first concentrated on the high mountain burns in the Engelmann spruce and lodgepole pine types, where it will pay the highest returns, both in direct and indirect benefits. From here it will extend downward into the Douglas fir burns, inferior aspen areas, and temporary brush lands. Last of all, the great permanent brush lands of the lower mountain slopes may be considered for planting with conifers, together with other areas lying on the border of potential forest land.

SUMMARY.

Reforestation by direct seeding is impracticable in the intermountain region. The planting of nursery-grown stock, on the other hand, has been successful under favorable site conditions.

The seed used in the nursery should have a high germinative energy and should be collected from trees of good form and development found in localities adjacent to the areas to be planted and having similar soil and climatic conditions.

The seedlings and transplants should be given sufficient water to produce vigorous plants, but an excess should be avoided. Where necessary, protection should be afforded against intense sunlight, frost, and snow molding. Unusually heavy, calcareous clay soils should be avoided for nursery purposes.

It is essential that the young tree, in order to become established when planted in the field, should be able to maintain a conservative balance between water absorption and water loss through transpiration. To accomplish this, the transplant must have a root system sufficiently long to reach into the soil strata which retain available

moisture, even through prolonged dry periods, and sufficient extensive development of actively-absorbing fibrous rootlets on the laterals to enable it to draw moisture from a large soil mass. In order to preclude excessive transpiration, the top must not be too large.

The best time to plant any species in the intermountain region is just as early in the spring following the disappearance of the snow as the soil can be worked. Growth of the stock must be retarded until after it is planted.

In selecting species for a planting site, the occurrence and development of native species growing on or adjacent to the site should largely govern. Native species have proved superior to exotics in every case tested. The native herbaceous and shrubby vegetation may be used as a further index.

In western yellow pine and lodgepole pine, the best stock is 2–1 transplants; with Douglas fir and the spruces, 3–1; or in the case of an exceptionally short-growing season the fourth year, 3–2 stock. Age class should be used as the criterion only in so far as it is indicative of the desirable qualities mentioned above.

Artificial forestation is destined ultimately to occupy a more important place in the management of the national forests of the intermountain region than at present.

In this region, where agricultural development is primarily dependent upon irrigation water derived almost altogether from national forest watersheds, watershed protection and water conservation through the equalization of stream flow are the primary objects to be achieved in forest planting, timber production on a commercial scale being of secondary importance. The best field for planting is in the high mountains, where relatively heavy stands can be grown which will have higher timber values as well as watershed protection values.

APPENDIX.

DESCRIPTIONS OF PLANTING SITES NOTED IN TABLES.

1. Planted on block E under dense, tall oak brush with a generally unbroken canopy about 5 feet above ground. North exposure, slope 25 per cent, elevation 7,200 feet. Soil silt loam to clay loam. Most of survivors under local breaks in the canopy.

2. On block E, immediately up hill to the south from the preceding plantations. Similar site in all respects except that the oak brush is about knee high and patchy.

3. On block Q, moderately dense oak brush on a north exposure, slope 40 per cent, 7,400 feet elevation, soil composed of 3 to 4 inches of humus over light brown clay loam, clay and gravelly or stony clay (limestone). The stock used in the first of the 1919 plantations listed is from Salmon National Forest seed, the second from Sevier National Forest. Owing to excessive rabbit damage these plantations were torn out at the end of the first year and replanted in the spring of 1920 inside a rabbit-proof (poultry wire) enclosure.

4. Planted on block Q, upon an area covered with oak brush of good development forming an uneven canopy 4 to 5 feet above the ground. Aspect west, slope about 15 per cent, soil much the same as on northern aspect preceding. The first four plantations listed are tests of classes of stock, the fifth is a check upon the results of the preceding year with 2–1 stock. The sixth and seventh are fall plantations. On the first, each tree was protected by a conical pile of oak brush built over it to protect it from the weight of snow, and hence snow-fungus damage. It was ineffective. The last is a plantation upon a portion of this site from which the oak was cut and the sprouts removed as they came up.

5. Planted near block Q on a west slope under moderate to excellent oak brush cover by common laborers. It is a portion of a large plantation set aside for intensive observation.

6. Planted on block 1 on a gentle west slope at 6,800 feet elevation. Site covered by clumps of oak; plantation was evenly spaced, and some of the trees were placed under oak shade and some in the open. Soil compact light yellowish clay loam, overgrazed and eroded to a certain extent. Used as a site for testing the age classes of stock.

7. Planted on block 2, a north aspect with 35 per cent slope, at 6,800 feet elevation in the tension zone between the piñon-juniper and brush types. Area is covered with scattered growth of mountain mahogany, bitter brush, piñon and juniper.

8. Planted near block Q, 7,400 feet elevation upon a south aspect, slight slope, a severe site as indicated by the presence of cactus among the sagebrush and oak clumps that cover the area. Soil is a dark compact, gray-brown silty clay loam, underlain by clay.

9. Planted next to block A in mixed sage and oak brush cover adjoining aspen. Elevation 7,600 feet, exposure to west, slight slope. The soil is a light-brown loam grading into clay loam, ground cover scant.

10. Planted on block Q, 7,400 feet elevation on a flat covered with dense sagebrush 2 to 3 feet tall. Part of the area cleared in the spring of 1917. Soil is colluvial wash from slopes; on the surface, a dark grayish-brown compact, silty clay loam succeeded by a light-brown compact clay to the depth of 15 to 20 inches, beneath which lies a stiff yellowish waxy calcareous clay.

11. Planted on block Q, 7,400 feet elevation upon a ridge, top and brow of ridge having a south exposure, covered with a low growth of manzanita 1 to 2 feet tall, interspersed with many openings. The soil is a yellow-gray and brownish very fine sandy loam overlying a grayish-pink moderately compact clay. Soil shallow, practically no humus.

12. Planted on block Q on south slope immediately below preceding. The ground cover here consists of isolated bushes of mountain mahogany and wild apple with many barren openings between the bushes. The soil is similar to the manzanita site above, but it tends to be deeper owing to colluvial accumulation.

13. Planted near block Q at 7,500 feet elevation on a west exposure, about 25 per cent slope. The ground cover consists of a mixture of serviceberry and oak, otherwise the site is similar to site 4.

14. Planted on block H, a Douglas fir burn on a north exposure (40 per cent slope) at 8,300 feet elevation, on a site where there was originally a great deal of alpine fir in admixture with the Douglas fir. The ground cover now consists chiefly of raspberry and bromegrass with some brushy species. The soil is a thin, light-brown, very fine sandy loam resting upon sandstone.

15. Planted on block A, under dense aspen cover at its lower limit (7,600 feet elevation). Exposure west, slope slight. The soil is a dark-brown compact clay, becoming lighter downward. In 1916 half of this area was severely thinned, after which a second planting was made. The results given are the averages of the original and thinned halves of the block.

16. Planted on block C, an area covered with aspen of medium density at an elevation of 8,300 feet. The exposure is west, the slope 6 per cent. The soil is a light brown very sandy loam grading into stony clay.

17. Planted on block R under varying degrees of aspen cover obtained by thinning a stand which was originally very dense. The light intensities secured by the thinning are: 0.08, 0.20, 0.28, 0.39, 1.00 (Clements photometer). The lower edge of the aspen zone, exposure north, slope 15 per cent (average) ranging from almost flat to 25 per cent. The soil is a brown moderately compact clay becoming lighter in color with depth. An area adjoining the aspen is also included in this block. It is characterized by snowberry cover, with virtually barren areas between the bushes. The soil is a sterile, brownish, crumbly calcareous clay.

18. Planted on block F, an old Douglas fir burn now thickly covered with many species of low brush. Exposure north, slope 50 per cent, elevation 8,300 feet. The soil is light-brown, very sandy, clay loam beneath which is a yellow-brown silty or very fine sandy clay.

19. This plantation was made in oak brush on what was known as the "Casto Ranch area." The soil is a brown, fine sandy loam, rather lighter in texture than on similar sites in Ephraim Canyon. The brush is moderately open and the trees stood between the clumps rather than beneath the canopy of the brush.

20. This plantation was made in a mixed brush type at about 6,800 feet elevation. Survival was different on open areas and those covered with sagebrush, and the records on these two sites have been kept separate. The soil is a fine sandy loam.

21. This site is upon a south slope at approximately 7,400 feet elevation in a mixed brush type composed of low, open growths of scrub oak, together with sagebrush, snowbrush, serviceberry, chokecherry, elderberry, and other shrubs. All the plantations except the eighth listed are directly north of the old Cottonwood Nursery site, the one exception being about 1 mile farther down the canyon. The soil is fairly light, rocky, probably fairly well watered at some depth by subterranean seepage, as many rather mesophytic species are found there such as aspen, elderberry, and chokeberry.

22. The temporary brush site lies on a Douglas fir burn, and is covered mainly by chokecherry, serviceberry, snowberry, and ninebark. This site, although too severe for the successful planting of Douglas fir, appears favorable for western yellow pine.

23. Located on a gentle northwest slope in scattering scrubby oak brush mixed with some chokecherry and *Symphoricarpos*. Soil is a rocky, gravelly loam. Altitude about 7,500 feet.

24. Located near the previous area on a similar gentle northwest slope. The original vegetation of sagebrush was grubbed out, leaving nothing but a few scattering stems of chokecherry, *Symphoricarpos*, and a few plants of *Carex*. The soil is a gravelly loam.

25. Adjacent to the previous plot; similar in all respects, except that it bears a fairly dense stand of sagebrush.

26. These plots are located in dense oak brush which does not grow very tall. The area probably once bore an open stand of Douglas fir, together with oak brush. Fires following logging 50 years or so ago killed out the Douglas fir. There is an exceptionally rank growth of other brushy and herbaceous species with the oak. Rabbit damage on these plots has been considerable. The first plantation listed was planted with stock from what was then the Sevier National Forest seed, the second from Salmon National Forest seed.

27. These plots are located in an extensive open flat which originally bore a heavy sagebrush cover. This was burned off in 1915 and in the two years following plantations were made, at which time the areas were covered with a dense growth of wild geranium. After 1917 the sagebrush began to come back little by little. The soil is a rather heavy brown silt loam The third, fourth, fifth, and sixth plantations listed on this site are tests of classes of stock planted side by side. Of the two plantations of 2–0 stock planted in April, 1916, which show 64 per cent and 66 per cent survival in the first year, the first was made with unskilled labor, and the second with technical labor on the same site. The 2–1 stock on the first plantation listed was from the Monument Nursery (Colorado). The second lot was from the Beaver Creek Nursery (Utah). Of these two plantations the first was on a slight southwest and the second on a northeast exposure.

28. This area is in scrubby aspen adjoining the sagebrush flat above described.

29. A northeastern aspect with moderate slope characterized by bitterbrush and snowberry. The soil is a heavy brown silty loam.

30. These plots are on a steep slope with a northeast aspect bearing a dense thrifty growth of snowbrush, serviceberry, myrtle brush, chokecherry, rose, and bitterbrush. The soil is coarser than on the sage and permanent brush types and is more favorable to plant growth. Many mesophytic herbs are found among the clumps of brush.

31. These plots are adjacent, one set on a northeast exposure, the other upon a nearly flat bench. The first planting on each site is by the center-hole method, the second by the slit method. The soil is a brown loam, well suited to the latter method. The area is covered with small aspen, intermixed with a few lodgepole pines and Douglas fir. There is a fair ground cover of pine grass and herbs. Ground squirrels and gophers did much damage.

32. Planted in block B, a flat covered with a mature stand of large aspen at 8,700 feet elevation. The aspen has been thinned to give 5 degrees of density having light values of 0.20, 0.30, 0.45, 0.60, and 1.00 (Clements photometer). The soil is a very fine sandy to compact loam. The damage from gophers has always been excessive here.

33. Planted on block K under uneven cover of young aspen following a burn about 15 years before. Exposure north, slope 15 per cent, elevation 9,200 feet, situated near the foot of a long slope. Soil is a light-brownish very fine sandy loam 8 inches deep over a stiff clay.

34. Planted on block 3. Conditions of site same as on block A, except elevation is somewhat higher, 7,800 feet, and the ground is covered fairly densely with myrtlebrush (*Pachystima myrsinites*).

35. Planted on block O. Conditions are virtually the same as on block C (site 16), which lies about one-eighth mile south, except that rabbit damage has been exceptionally severe.

36. Plantation made on block D, in a hollow covered with large dense aspen of first quality. Exposure south, nearly flat, elevation 8,500 feet. Soil is a dark-grayish clay moderately friable when dry, 1 to 3 inches of forest mold on the surface. The forest floor is quite brushy and there is little light.

37. Planted on block G, an old burn in the spruce-fir type on a steep north exposure (slope 50 per cent), at an elevation of 9,500 feet. The area still shows some down timber; it is heavily sodded except in the vicinity of gooseberry and elder bushes. Snow is heavy and lies late in the spring upon this site.

38. Planted on block M, located on a south exposure at 8,700 feet elevation, slope 25 per cent. The plantation on this area is located half in the open and half in light scrubby aspen cover. The open portion of the area is an overgrazed barren stony area, a very severe site. Soil under aspen somewhat better. Figures given show average survival on whole plot, although nearly all the trees planted in the open half died within a year.

39. Planted on block O, on a flat ridgetop having a slight slope to the northwest at 8,100 feet elevation. The site is a small patch of dense sagebrush about 2 feet tall, nearly surrounded by aspen type. Soil is a brown silt loam grading into a light-brown compact clay loam.

40. Planted on block N at 7,500 feet elevation on an area covered with sagebrush and with some oak in mixture. The area is nearly flat, having a slight slope of 5 per cent to the west. The soil is a dark-gray, silty clay loam succeeded by a light-brown clay at the depth of a few inches.

41. Planted on block O over a flat ridgetop at 8,100 feet elevation which has a virtually complete cover of manzanita brush 2 to 3 feet high. The soil is a light-brown very fine sandy loam underlain by a very stony (sandstone) soil of the same composition. The soil is shallow.

42. Planted on block O. There is considerable deep shade from scattered white firs on this site, and around these trees a deep conifer duff.

43. Planted near block Q in oak brush on a steep north slope at 7,400 feet elevation. Soon after planting a road was cut through the area. The figures on survival the fourth year are from that portion of the area which was not affected by the road. The site is similar to the following.

44. On block Q in moderately dense oak brush on a north exposure, slope 40 per cent, 7,400 feet elevation, soil composed of 3 to 4 inches of humus layer over light-brown clay loam, clay, and gravelly or stony clay (limestone).

45. The plantations in aspen in Big Cottonwood Canyon were not all on one compact area, but they were not far separated. All were at an elevation of about 7,500 feet to 7,800 feet, and all were on north to northeast exposures with steep slopes. The aspen is fairly dense, of small size (4 to 6 inches in diameter), the ground cover is scanty, herbaceous, or grassy. On the forest area listed in Big Cottonwood Canyon, there is a rather dense growth in midsummer of grass, *Rudbeckia*, and some shrubs.

46. This area adjoins one of the aspen areas. The grass and herbaceous cover is dense. Otherwise the site is similar to the previous one.

47. These plots are located in dense oak brush which does not grow very tall. The area probably once bore an open stand of Douglas fir together with oak brush. Fires following logging 50 years or so ago killed out the Douglas fir. There is an exceptionally rank growth of other brushy and herbaceous species with the oak. Rabbit damage on these plots has been considerable. The first plantation listed was planted with stock from Sevier National Forest seed, the second from Salmon National Forest seed.

48. This plantation is located in a small patch of moderately dense, rather scrubby aspen adjacent to a sagebrush flat. The slope is gentle, aspect north, elevation about 7,000 feet. There is a light ground cover of grass and weeds. The soil is a light gravelly loam.

49. The 2–1 and 2 1/2–0 stock used on three of these plantations came from the Gallinas Nursery (New Mexico) and received different amounts of shade in the transplant beds. These plantations are all in a rather scrubby aspen type, adjoining a large sagebrush basin, slopes are gentle, aspect east to northeast. The ground cover is moderate, grasses and herbs. The soil is a brown silty loam, rather heavy. The last two plantations on this site lie side by side at some little distance from the rest, and on more moist land.

50. These plantations are all in the aspen type, those near the bench being just over the brow of the hill from those on the slope. The aspen is in a rather broken stand, with a ground cover of pine grass and herbs. Ground squirrels or gophers have done great damage on the bench. There is a very scattered natural growth of Douglas fir and lodgepole pine on the areas, especially upon the slopes.

51. A site in dense young aspen near the lower limit of its growth in the hills fringing the Teton Valley. The soil is a sandy loam. There is a dense ground cover of pine grass (*Calamagrostis rubescens*). Exposure west, slope moderate.

52. Planted on block P at 9,800 feet elevation in the spruce-fir zone under dense and medium aspen and in the open adjoining. The site is on a flat bench protected by a high ridge to the south and west. The soil is a light-brown clay loam underlain by yellowish or grayish clay. At the time of planting it was dry, hard, and cloddy in the aspen, but fresh and moist in the open, owing to the location of snowdrifts on the area.

53. Planted on block S, Engelmann spruce burn not restocking and still covered with much down timber. The exposure is north, slope 25 per cent, elevation 9,900 feet. The soil is a rich mellow loam of limestone origin. The area is heavily grazed by sheep and cattle and the trees are planted close to stumps and down timber. This area is not in the Ephraim Canyon drainage, but is opposite its head in Seeley Creek (Colorado River drainage).

54. All these aspen sites are similar in being located in aspen cover of moderate density on northeast exposures. They are scattered upon three areas, however, which vary in minor ways. The first was located on block A to the east of the Cottonwood Nursery site, at an elevation of 7,600 feet, not much above the level of the valley floor. This location is characterized by a rich moist loam soil, and dense aspen cover. The ground is open at planting time, but later in the season it becomes a jungle of elder, nettles, *Rudbeckia*, *Thalictrum*, and *Washingtonia*, which, added to the *Symphoricarpos* on the ground makes a very dense shade and strong root competition.

55. These plantations are on block B on the hill immediately to the southwest of the Cottonwood Nursery across Day's Fork at an altitude of about 8,100 feet, some 600 feet above the canyon floor. They are different from the preceding

areas in having a brushy rather than an herbaceous undergrowth, characterized by willow, alder, myrtlebrush, *Ribes viscosissimum*, and ninebark. This brush is very dense on the first two plantations and only moderately dense in the case of the third. The soil is a sandy loam containing some rock.

56. The site upon which these five plots are located is known as block F, and lies near block B on the west side of Day's Fork at an altitude of about 7,800 feet, 400 feet above the canyon floor. This site differs from the two preceding in having a moderate cover of grasses and herbs, and only scattered brush. Vegetative competition is not so severe as on the other sites.

57. This plantation is located at some distance from the others, on a west exposure, with a gentle slope in aspen, in Mill D North Fork, at an elevation of about 7,800 feet. The soil is a deep dark loam, apparently fairly moist, considering the aspect. Ground cover is mainly herbaceous, with a scattering of *Symphoricarpos*, and is not very dense.

58. This plantation is located on a fairly recent burn, still log strewn, and not dominated by a closed stand of brush. It lies up hill above the area described as site 54. The soil is a deep sandy rocky loam. The brushy species which characterize the area are *Symphoricarpos*, elder, mountain ash, willow, maple. Elevation is 7,700 feet.

59. This plantation is located near the aspen area described as site 55. It is situated on a northeast exposure at 8,100 feet elevation on a fairly recent log-strewn burn covered with an open stand of scrubby small aspen, willows, and maple. The soil is a deep sandy loam.

60. This area is near the previous one noted, but the brush is dense, consisting of the same species noted above, aspen, willows, maple, together with *Ribes viscosissimum* and myrtlebrush.

61. Planted on block G, an open grassy area occupying an old burn in the spruce-fir type. The trees have all fallen and have mostly rotted away. A dense sod covers the area, and this increased its density notably since the area was fenced. There are a few clumps of elder and spring *Grossularia*. No natural reproduction is coming in on this area.

62. The site is the same as site 56, except it bears no aspen. The brush and herbaceous vegetation are similar.

63. Planted on a bench sloping northwest covered with a fair growth of sagebrush, together with occasional specimens of *Symphoricarpos*, chokecherry, and small aspen. The altitude is 7,450 feet. The sagebrush was all grubbed out on part of this area prior to the planting.

64. Planted on a bench with a very gentle slope, northwest aspect, covered with aspen of somewhat varying density interspersed with a few young lodgepole pines, and such brushy species as sagebrush, *Symphoricarpos*, snowbrush, and chokecherry. The elevation is about 7,400 feet. The first of the four plantations is under pure aspen, and very few brushy species are present, there being merely a scanty herbaceous cover.

65. Planted in sagebrush type on a very gentle slope with north exposure. The soil is a rocky loam derived from limestone.

66. Planted near the area just noted but in aspen cover; slope, exposure, and soil are similar.

67. No data exist in the records describing this site in detail. It is on the Shingle Creek planting area, the first plantation being made by common labor, the second by technically trained men.

68. Planted on a moderately steep north exposure in fairly dense sagebrush cover. The soil is a deep loam. Besides the sage, there is a light cover of grass and weeds. It is near the Elbow Canyon Ranger Station at 6,500 feet elevation.

69. Planted on a small flat where a draw enters Montpelier Canyon below Elbow Ranger Station. Altitude is 6,900 feet. The slope is very gentle, with an eastern exposure. The soil is a deep loam. The cover is open aspen, the ground being covered with a fairly dense growth of pine grass.

70. These plots are located in an extensive open flat which originally bore a heavy sagebrush cover. This was burned off in 1915 and in the two years following, plantations were made, at which time the areas were covered with a dense growth of wild geranium. After 1917 the sagebrush began to come back little by little. The soil is a rather heavy brown silt loam. While all three plantations were located in this same general type, they were not on precisely the same sites, the first being on an eastern exposure, the second and third on flats.

71. All seven of these plantations are close together, some on a bench above the brow of the hill, and some on the slope below. The area is covered with an irregular stand of aspen interspersed with some lodgepole pine and Douglas fir,

with a ground cover of pine grass. The soil is a light sandy loam. Rodent damage has been severe on all these plots, especially those on the bench.

72. Planted on a small grassy opening between broken stands of aspen, on a west exposure with a gentle slope. The soil is a gravelly sandy loam, apparently fairly well watered. The ground cover is largely pine grass and *Carex* of moderate density. A few aspen root suckers are coming up on the area, but are too scattered and small to cast appreciable shade. Altitude 6,900 feet.

73. All three of the plantations in aspen are upon the same general moderate slope of a westerly aspect. The first plantation is at a somewhat higher elevation than the next two in the list, being at 6,900 feet in a small area of aspen adjacent to the opening described as site 72 above. The aspen is moderately dense, ground cover is scant. The lower area is in smaller, denser aspen with a rather dense ground cover of pine grass.

74. Planted in a recent Douglas fir burn on a moderate slope with a northwesterly exposure. The soil is a sandy loam. The ground cover is of moderate density, consisting of many species of herbs, grasses, and shrubs. Natural lodgepole pine reproduction is coming in on the area. The first plantation was made by common labor, the second by skilled technical labor.

75. Plantation made on block O in a site similar to that mentioned in the description of site 35, and about 200 yards distant. The area is on the edge of the aspen type, half the plantation being in aspen and half in brush immediately to the north and shaded considerably from direct sun by the aspen stand.

76. Planted on block O on the top of a flat ridge at 8,100 feet elevation, in an area covered with aspen of very poor quality with a nearly suppressed understory of manzanita. There is an active invasion of Douglas fir and white fir on the area. The soil is unusually sandy for the Ephraim Canyon drainage, similar to the manzanita site adjoining on which Douglas fir and lodgepole pine were planted. It consists of a light brown very fine sandy loam underlain with a yellowish gravelly to stony very fine sandy loam which grades into a grayish clay at 15 to 20 inches.

77. This site is only about 50 yards from the preceding and adjoins the area mentioned as site 35. It is located in a small natural opening in the aspen which is virtually barren (overgrazed), soil conditions are like the near-by areas.

78. In aspen of variable density, averaging intermediate on a moderate slope, east exposure at 8,100 feet elevation. The soil is a sandy clay loam. The ground cover is thin, composed of grasses and herbs.

79. In a patch of oak brush of moderate density, on a gentle slope, east exposure at 8,100 feet elevation. The soil is a deep-black clayey, sandy loam. The ground cover is of scattered grasses and herbs.

80. All of these plantations were made upon the same general site, an old burn in the spruce-fir type. The area came up to a broken, open stand of aspen after the fire, the openings being covered with sage and weeds. These plantations were made in long single lines and traversed some aspen cover and some sagebrush openings. Records were kept separately on the two sites. In general, the area is characterized by moderate slopes with north and northeast exposures. The soil is a rich sandy loam. The aspen cover is light, and in the openings the sagebrush is small and scattered, being intermixed with many herbaceous species. The elevation is 7,400 feet, rather low for spruce.

81. Planted on Area A to the east of the Cottonwood Nursery at an elevation of 7,600 feet, not much above the level of the valley floor. This location is characterized by a rich, moist loamy soil and dense aspen cover. The ground is open at planting time, but later in the season it becomes a jungle of elder, nettles, *Rudbeckia*, *Thalictrum*, and *Washingtonia*, which added to the *Symphoricarpos* on the ground, makes a very dense shade and strong root competition.

82. Planted on Block F, an area covered with aspen of moderate density upon a northeast exposure with moderate slope at an elevation of 7,800 feet, 400 feet above the level of the canyon floor. It has a moderate cover of grasses and herbs.

83. Planted in aspen of moderate density, intermingled with scattering alpine firs, upon a gentle slope, north exposure. Altitude is 7,300 feet, scarcely above the canyon floor level. The ground cover is moderate, consisting of such brushy species as snowbrush, *Symphoricarpos*, myrtlebrush, elder, together with grasses and herbs. The soil is a sandy, silty loam.

84. Planted in thin scrubby aspen cover on Shingle Creek. The first was planted by skilled technical labor and the second by common labor. These two plantations are in rocky, clay loam soil on a northwest aspect. Ground cover consists mainly of such shrubs as rose, *Symphoricarpos*, chokecherry, and nine-

bark. The third plantation is on a gentle slope with northeast exposure. The soil is less rocky, a clay loam. There are no shrubby associates of the scrubby aspen, the scanty ground cover being composed of grasses and herbs.

85. Planted on a moderate slope with northeast aspect in permanent brush type composed of many species such as serviceberry, ninebark, rose, myrtlebrush. The soil is a shallow loam, with a heavier subsoil near the surface. Altitude is 6,200 feet.

86. Planted near the preceding in aspen cover of moderate density. The exposure here is north, the slope moderate, and the soil is a sandy loam.

87. Planted on a flat in an irregular stand of aspen interspersed with sage openings. The soil is a sandy loam.

88. These four plantations are adjacent, two on a flat above the brow of a hill, two on the slope below. The entire area is covered with an open stand of aspen, interspersed with young lodgepole pine and Douglas fir. The aspen is more dense and uniform on the slope than on the flat. The ground cover on the slope is pine grass; on the flat there is considerable *Symphoricarpos*. Burrowing rodents have done much damage, especially on the flat bench. The first plantation listed on each site was planted by the center-hole method, the second being by the slit method.

89. Planted on a spruce flat burned over in 1910 on the south side of Darby Canyon at 6,600 feet elevation. There is a heavy sod on the area. The soil is a sandy loam.

90. Planted in the bottom of a ravine entering Darby Canyon from the south at an elevation of 6,600 feet. The slope is gentle and aspect west. The soil is a rocky clay loam. The ground is covered with a moderate herbaceous and grass cover heavily grazed in summer. This area has been logged but not burned.

91. Planted in the lower aspen on the west exposure south of the mouth of Darby Canyon. The aspen is dense and there is a dense cover of pine grass sod on the ground. The soil is a sandy loam. The slit method of planting was used. Altitude is 6,600 feet.

92. This plantation is in a mixed brush type of willow, ninebark, snowbrush and rose, mixed with various herbaceous species on an old burn in Darby Canyon. The slope is moderately steep. The exposure north. The altitude is 6,850 feet. The soil is a very rocky clay loam.

93. Planted on block L, in the middle of the natural blue spruce range at 7,800 feet elevation on a well-watered flat with a slight north exposure. Natural blue spruce exists upon the area. The soil is a heavy clay loam, wet in spring and likely to bake in summer. The plantation has been partly destroyed by a small flood and by the digging of a pipe line trench through the area.

94. Planted on block J at an elevation of 8,900 feet, above the natural limit of blue spruce, along a small intermittent mountain torrent, exposure northeast, slope 40 per cent. The ground is covered in the summer with a dense growth of elderberry and niggerhead (*Rudbeckia occidentalis*), and in winter is subject to snowslides. The soil is a brown clay loam underlain by brownish or grayish clay. The surface layer consists of only partly decomposed vegetable material brought down by snowslides.

95. Planted in aspen of average density on a north exposure, moderate slope, immediately adjacent to the Cottonwood Nursery. Plants placed in favorable spots fairly free from competition.

96. There is little description of this site in the records.

97. These two plots are located on the slope and on the flat at the foot of the slope, respectively, and adjacent. The general site is on the south side of the canyon in an old Douglas fir burn, grown up to brush, willow, ninebark, rose and snowbrush mainly. The flat has a moderate sod, while the slope bears only a scattering of herbs among the brush.

98. Planted in thin aspen adjacent to a sage flat. The cover is light, ground cover scant grass and herbs, the slope very slight, with an easterly exposure.

99. Planted in a large sagebrush flat burned over the previous year, and bearing a dense cover of geranium. The site is almost flat, the soil a rather compact silty loam.

100. These plots are adjacent, one set on a northwest exposure, the other upon a near-by flat bench. The first planting on each site is by the center-hole method, the second by the slit method. The soil is a brown loam, well suited to the latter method. The area is covered with small aspen, intermixed with some lodgepole pine and Douglas fir. There is a fair ground cover of pine grass and herbs. Ground squirrels and gophers did much damage.

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December 30, 1924.

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